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PROGRESS REPORT
TO
OFFICE OF NAVAL RESEARCH

FOR CONTRACT NO: N00014-90-C-0123

TITLE: **Development of an Expendable Particle Sensor**

ITEM NO: **0001AJ**

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Arlington, Virginia

Per Anne Watson, she has no way of getting the missing pages. The reports that are sent to us is all that she has. When she get the pages they will be sent to DTIC with distribution.

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Introduction:

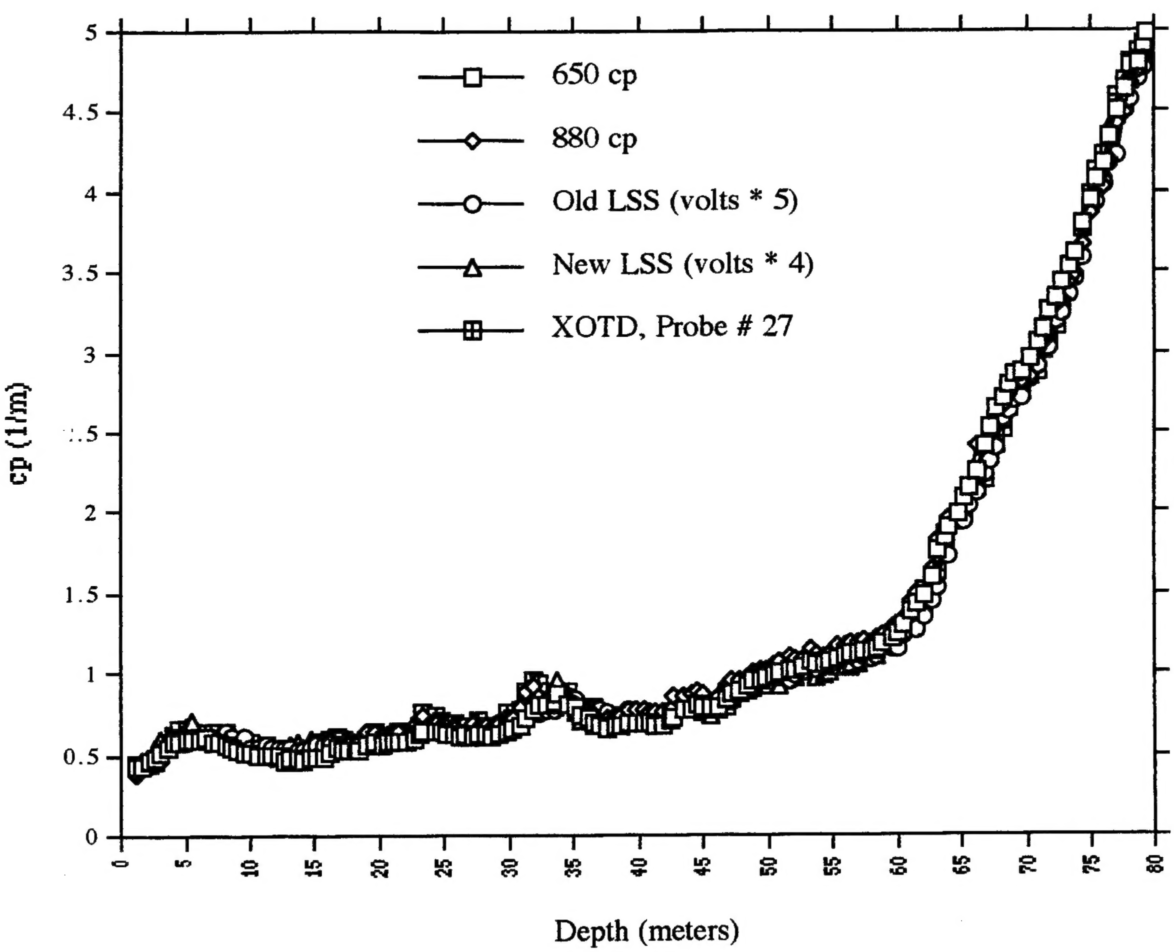
This report addresses progress on the Development of the Airborne and Ship Deployable Expendable Particle Sensor, A&XOTD from 2/93 to 2/94.

A&XOTD Development Progress:

Sparton has developed a prototype AXOTD and qualified the device for airborne deployment. Since their was no change in the physical parameters of the airborne package, the qualification the AXOTD for airborne deployment was simply a paper exercise.

The A&XOTD has been tested in the laboratory and the field and performs well. The device was deployed from Sea Tech's research vessel into 80 meters of fresh water at Green Peter reservoir and 18 meters of water at Foster reservoir, both reservoirs are located near Sweet Home Oregon. A&XOTD data was obtained by first installing the expendable probe on Sea Tech's optical data acquisition system, (STODAS) allowing the probe to be calibrated. Then the probe was dropped into the water and profiles were compared to determine the performance of the expendable probe. Figure 1 is typical of the data obtained during the field tests and demonstrates that the A&XOTD light scattering sensor correlates very well with the 650 nm, 880 nm transmissometers. Figure 1 also shows no difference in output between the old and new Sea Tech LSS design and the Sparton expendable XOTD LSS design. A&XOTD temperature data shows the correct profile but was not closely evaluated because of a malfunction of the Sea Tech fast response temperature probe. The field test log and data are included in appendix A. Analysis of data and field test problems are included in appendix B.

Figure 1 LSS, Old Design - LSS, New Design - LSS, XOTD Design
vs 650 & 880 nm cp in Fresh Water



Field Test Experiment:

The deployment of the A&XOTD expendable probes was done using 15 LB. test fishing line attached to the probe permitting the recovery of the expendable units. Drop rate can not be determined from these tests due to the drag imposed by the fishing line. To determine actual drop rate three probes were allowed to free fall and were not recovered. Comments and analysis of the field test data will be found in the field test log listed in appendix A and B. The main objective of the field tests were to determine stability and repeatability of both the expendable probes and the Sparton computer interface card.

The Sea Tech optical data acquisition system, STODAS was used to obtain profiles of the optical parameters as well as depth and temperature in the water column. The A&XOTD profiles were compared with data taken with the STODAS to evaluate the performance of the expendable probes. The optical parameters measured were the beam attenuation coefficient, c at two wavelengths, 650 nm and 880 nm, the beam absorption coefficient, a at 880 nm, secci depth, fluorescence and light scattering at 880 nm with both the old and new Sea Tech LSS.

The field test data shown in appendix A validates that the A&XOTD probes function properly from an optical point of view. Certainly more work is required from a system point of view to acquire reliable and accurate data. Any final conclusions regarding the accuracy of the expendable probes or the probe drop rate are at this time premature because of the problems listed below. What can be concluded from this field test data are that the optical and temperature sensors in the A&XOTD probes function properly and to acquire accurate data more attention must to be paid to the calibration of these sensors.

Problems encountered during the field test:

1) The Sparton computer interface card did not function properly resulting in unreliable start time and sample time. This problem did not prevent the acquisition of data needed to determine the basic performance of the optical probe.
2) Drop rate can not be evaluated because in most cases the drops were done with a fishing line attached to the probes allowing recovery of the probe permitting data to be obtained related to the repeatability and stability of the optical sensor.
3) Because of unreliable start and sample time, most of the data obtained by dropping the A&XOTD probes was edited to match optical profiles taken with the STODAS. Not all of the data acquired was plotted in appendix A due to the unreliable nature of the data, however; sufficient data is presented to evaluate the basic performance of the optical and temperature sensor which again was Sea Tech's main objective for this field test.

Hydrodynamic Performance of the Expendable Probes:

Based on the LSS data obtained in the reservoirs above during this field test, the A&XOTD probe boundary layer thickness and flow separation does not appear to be a problem in moderately turbid water To be completely sure that their is not a problem with probe boundary layer thickness and flow separation the probe needs to be evaluated in very turbid water since this is when the sample volume will be very close to the probe surface, < 5 mm for 1 g/l, see appendix C. The sample volume in water is described in appendix C. Problems with drop rate appear to remain and certainly needs further evaluation. Given that start time is reliable for the final field tests this will be simple to accomplish because the optical sensor permits an accurate measurement of the time the probe reaches the bottom.

Future Work:

The only significant AXOTD engineering problems remaining are the performance of the Sparton computer interface card. The data output is not stable and Sparton believes that this is a software problem. This problem will be fixed by Sparton prior to final field tests. Sea Tech will evaluate the Sparton computer interface in the field using existing prototype XOTD sensors prior to the final field tests to insure accurate data is obtained. To further insure success Sea Tech will also provide a back up computer interface to receive and record the expendable probe data for the final field tests. The final field tests of the expendable A&XOTD probes will hopefully be evaluated during a cruise coordinated and attended by NRL scientists.

Appendix A

Field Test Log & Data

Field Test Log

9/30 through 10/4/93

Field Test Log

Sea Tech. and Sparton field test data for the A&XOTD from September 30 to October 4, 1993.

The field test log is arranged in chronological order and the test data are separated into casts and drops. Again casts were done to calibrate the expendable probes and drops were done to access the probe performance when dropped rapidly through the water column. The field test data includes cast 1 to 28 and drop 1 to 24 with some exceptions where data was unreliable or missing it was not plotted. Drop 24 through 41 was not plotted simply because at some point one must say it ends here, it took over two months to clean up and edit the data presented so that reasonable plots could be obtained. The main problem again was that the Sparton computer interface did not function properly resulting in very unreliable start times. The problems encountered and the data from casts 1 through 9 and cast 20 in conjunction with drop 17 are presented in the data analysis section, appendix B of this report to summarize the performance of the expendable probes.. For those who are only interested in the bottom line, I suggest you now turn to appendix B.

For all casts, synchronization of the data from the XOTD and AXOTD which is taken at 12 samples per second with the data taken by the STODAS at one sample per second was accomplished with a computer program that averages the A&XOTD data into one second intervals. The STODAS data recorder was started prior to taking a cast and the offset or delay time for water entry of the expendable probe was recorded. This allows for synchronization of the STODAS data and the expendable probe data since the expendable probe data does not start until the sea water switch on the expendable probe penetrates the water.

The primary objective of all the following tests are to determine if the optical profiles, cp Vs light scattering obtained during casts are the same as those obtained during drops where the decent rate of the expendable probes are much faster.

A careful evaluation of the temperature data was not done since the Sea Tech fast response temperature probe was found to be inaccurate and unreliable. A slow response temperature probe was used on the last day of the field test but will not show the fine scale structure needed to accurately determine the accuracy of the A&XOTD temperature sensor. Some temperature plots were done to demonstrate that the A&XOTD temperature sensor functioned properly.

September 30, 1993

All casts for this day are at Green Peter Reservoir. The boat is tied up at the log boom near the dam, N44° 27.106', W122°32.803'. Bottom depth as measured by the sonar system on the boat is 85 meters. The wind is blowing causing some drifting across our cast point. XOTD probe # 45 is mounted on the STODAS. Surface temperature is 19.1 °C.

3:19:45 PM PDT, N44° 27.106', W122°32.803'

> Cast is GP1, bottom depth is 85m, cast depth is 75m. Offset time for XOTD # 45, file X045-1, is 1:08. Secci depth is 7m. XOTD did not function properly, no data after 2 seconds.

4:28:00 PM PDT, N44° 27.106', W122°32.803'

> Cast is GP2, Bottom depth is 82m, cast depth is 78m. Offset time for XOTD # 45, file X045-2, is 1:42, Secci depth is 7m

5:35:00 PM PDT, N44° 27.106', W122°32.803'

> Cast is GP3, Bottom depth is 78m cast depth is 72m, offset time for XOTD # 45, file X045-3, is 1:11, Secci depth is 6.5m

5:59:30 PM PDT, N44° 27.106', W122°32.803'

Cast is GP4, bottom depth is 80m, cast depth is 79m. Offset time for XOTD # 45, file X045-4, is 1:26. Secci depth is 6.5m

6:21:15 PM PDT, N44° 27.106', W122°32.803'

Cast is GP5, bottom depth is 84m, cast depth is 82m. Offset time for XOTD # 45, file X045-5, is 1:32. Secci depth is 6.5m

6:40:15 PM PDT, N44° 27.106', W122°32.803'

Cast is GP6, bottom depth is 84m, cast depth is 82m. Offset time for XOTD # 45, file X045-6, is 0:55. No Secci depth.

October 1, 1993

All cast for this day are at Green Peter Reservoir, log boom, tied up at N44° 27.106', W122°32.803'. Surface temperature is 19.1 °C.

3:45:45 PM PDT, N44° 27.106', W122°32.803'

Cast is GP7, bottom depth is 84m, cast depth is 77m. Offset time for XOTD # 45, file X045-7, is 1:12, Secci depth is 7.5m. No XOTD data, wire broke.

4:47:00 PM PDT, N44° 27.106', W122°32.803'

Drop 1, XOTD # 45, file X045-8, bottom depth is 84m, lower spool fish line deployment, felt occasional tugs on wire. The graph for drop 1 shows the same optical profile for a slow cast and the free decent rate of the probe. The temperature probe accuracy can not be evaluated since the Sea Tech temperature probe is not accurate never the less the XOTD temperature appears to be functioning properly.

6:11:30 PM PDT, N44° 27.106', W122°32.803'

Cast is GP8, bottom depth is 84m, cast depth is 84m (hit bottom) Offset time for XOTD # 45, file X045-9, is 1:12, Secci depth is 7.5m.

6:36:00 PM PDT, N44° 27.106', W122°32.803'

Cast is GP9, bottom depth is 84m, cast depth is 84m. Offset time for XOTD # 45, file X045-10, is 0:58, No Secci depth. XOTD data is N.G. XOTD optical sensor does not function, did not function on drop 2 either. See drop 2 plot.

7:06:00 PM PDT, N44° 27.106', W122°32.803'

Drop 2, XOTD # 45, file X045-11, bottom depth is 84m, lower spool fish line deployment, felt occasional tugs on wire. XOD data is N.G. and decent rate is low. See drop 2 graph. Temperature does not repeat, compare with drop 1. Since the XOD did not function temperature was plotted to determine if probe dropped at the drop 1 rate of 6 m/sec. It does not drop at the same rate, compare temperatures of drop 1 and drop 2. It is obvious that the same probe dropped twice under the same conditions does not drop at the same rate!! Even though Sea Tech temperature is not accurate it is plotted to raise the question, is the response of the thermistor fast enough at shallow depths. The data shows that the dip in temperature at the start of the cast is averaged out by the thermistor in the expendable probe. Questions: How rapidly is flow established across the thermistor and what is the response time in water.

Note:

Considerable difficulty was experienced on Oct. 1st with the fish line deployment from the lower spool. This scheme works but is unreliable and very time consuming; for this reason subsequent drops will be made using a nearly friction free spinning reel, and attaching a fishing line directly to the expendable probe allowing for retrieval of the probe so that stability data on each probe can be obtained. This will slow the probe decent rate because the probe must now drag the fishing line and the transmission wire through the water column. This problem is not very significant since we already know

from previous tests and the above data confirms that the hydrodynamic design of this probe is flawed. For these reasons little emphasis will be placed on drop rate in the following tests. Depth data will be calculated to match optical profile features and the drop rate will be ignored since it is unreliable. It is obvious from the optical data that the time the probe hits the bottom will be easy to determine. Subsequent data shows that determining the time from start to the time the probe hits the bottom is not trivial because the Sparton computer interface did not function properly. After the tests were done it was determined that the actual start time was unreliable. This problem caused data reduction to be very difficult and time consuming.

October 2, 1993

All cast for this day are at Green Peter Reservoir, log boom near dam, tied up at N44° 27.106', W122°32.803'. Slight wind blowing, enough to move cast location and change bottom depth.

11:52:30 AM PDT, N44° 27.106', W122°32.803'

Cast is GP10, bottom depth is 77m, cast depth is 75m. Offset time is 2:00 for XOTD # 52, file X052-1. Secci depth is 8.1m.

12:16:30 PM PDT, N44° 27.106', W122°32.803'

Cast is GP11, bottom depth is 76m, cast depth is 75m. Offset time is 1:14 for XOTD # 52, file X052-2. Secci depth is 8.1m.

12:37:15 PM PDT, N44° 27.106', W122°32.803'

Cast is GP12, bottom depth is 75.5m, cast depth is 75m. Offset time is 2:34 for XOTD # 56, file X056-1. Secci depth is 8.1m.

12:53:15 PM PDT, N44° 27.106', W122°32.803'

Cast is GP13, bottom depth is 75m, cast depth is 74m. Offset time is 1:16 for XOTD # 56, file X056-2. Secci depth is 8.2m.

1:37 PM PDT, N44° 27.106', W122°32.803'

Drop 3, XOTD # 56, file X056-3, bottom depth is 75m. First drop with fish line attached to XOTD and wire from surface spool.

1:42 PM PDT, N44° 27.106', W122°32.803'

Drop 4, XOTD # 45, file X045-N1, bottom depth is 75m. Lower spool fish line deployment, false start. No data and no plot.

2:03 PM PDT, N44° 27.106', W122°32.803'

Drop 5, XOTD # 52, file X052-3, bottom depth is 75m. Deployed with fish line attached to XOTD and wire from surface spool, wire snag resulting in bad data, no plot.

2:06 PM PDT, N44° 27.106', W122°32.803'

Drop 6, XOTD # 52, file X054-4, bottom depth is 75m. Deployed with fish line attached to XOTD and wire from surface spool.

2:48 PM PDT, N44° 27.106', W122°32.803'

Drop 7, XOTD # 56, file X054-4, bottom depth is 75m. Deployed with fish line attached to XOTD and wire from surface spool.

3:00:30 PM PDT, N44° 27.106', W122°32.803'

Cast is GP14, bottom depth is 73m, cast depth is 71m. Offset time is 1:26 for XOTD # 48, file X048-1. Secci depth is 8.1m.

3:16 PM PDT, N44° 27.106', W122°32.803'

Drop 8, XOTD # 52, file X052-5, bottom depth is 73m. Deployed with fish line attached to XOTD and wire from surface spool.

3:23:30 PM PDT, N44° 27.106', W122°32.803'

Cast is GP15, bottom depth is 70m, cast depth is 69m. Offset time is 1:06 for XOTD # 48, file X048-2. Secci depth is 8.1m, this cast had visible bubbles to 10m on down cast

3:53 PM PDT, N44° 27.106', W122°32.803'

XOTD optical zero test. XOTD # 48, file X048-OPT. Optical zero test. In and out of water to determine zero in air and zero in water. Air 0 to 14 sec, water 15 to 28 sec, air 29 to 41 sec and finally water 42 to 53 sec. Noise was +/- 0.025 % or 0.05% to 0.075% peak to peak. Compared, twice as high as Sea Tech prototype sensors.

3:59 PM PDT, N44° 27.106', W122°32.803'

Drop 9, XOTD # 48, file X048-3, bottom depth is 69m. Deployed with fish line attached to XOTD and wire from surface spool, false start.

4:15:45 PM PDT, N44° 27.106', W122°32.803'

Cast is GP16, bottom depth is 70m, cast depth is 69m. Offset time is 1:05 for XOTD # 50, file X050-1. Secci depth is 7.5m. STODAS temperature probe data is intermittent.

4:35 PM PDT, N44° 27.106', W122°32.803'

Drop 10, XOTD # 48, file X048-4, bottom depth is 70m. Deployed with fish line attached to XOTD and wire from surface spool, false start. Data N.G. not plotted.

5:15:15 PM PDT, N44° 27.106', W122°32.803'

Cast is GP17, bottom depth is 69m, cast depth is 68m. Offset time is 0:56 for XOTD # 50, file X050-2. Secci depth is 7.5m. Fluorometer and Temp channel are swapped!!

5:30:20 PM PDT, N44° 27.106', W122°32.803'

Cast is GP18, bottom depth is 69m, cast depth is 68m. Offset time is 1:08 for XOTD # 27, file X027-1. Secci depth is 7.5m. Fluorometer and Temp channel are swapped!!

5:54 PM PDT, N44° 27.106', W122°32.803'

Drop 11, XOTD # 50, file X050-3, bottom depth is 69m. Deployed with fish line attached to XOTD and wire from surface spool. False start dip and pull up then drop.

6:00:00 PM PDT, N44° 27.106', W122°32.803'

Cast is GP19, bottom depth is 70m, cast depth is 69m. Offset time is 1:39 for XOTD # 27, file X027-2. Secci depth is 7.0m. Fluorometer and Temp channel are swapped!!

Oct.ober 3, 1993

All cast for this day are at Green Peter Reservoir, log boom, near dam tied up at N44° 27.106', W122°32.803'.

2:15 PM PDT, N44° 27.106', W122°32.803'

Drop 12, XOTD # 50, file X050-4, bottom depth is 80m. Deployed with 12 LB test fish line attached to XOTD and wire from surface spool.

2:56:15 PM PDT, N44° 27.106', W122°32.803'

Cast is GP20, bottom depth is 80m, cast depth is 79m. Offset time is 1:40 for XOTD # 27, file X027-3. Secci depth is 7.8m. Fluorometer and Temp channel are swapped!! Lifted STODAS to check pumps.

4:03 PM PDT, N44° 27.106', W122°32.803'

Drop 13, XOTD # 27, file X027-4, bottom depth is 80m. Deployed with 12 LB test fish line attached to XOTD and wire from surface spool. Old optical sensor housing.

5:02 PM PDT, N44° 27.106', W122°32.803'

Drop 14, XOTD # 50, file X050-5, bottom depth is 80m. Deployed with 12 LB test fish line attached to XOTD and wire from surface spool. Added extra nose weight. Trajectory nearly horizontal near the surface. Probe stuck in mud and was unable to retrieve, lost probe.

5:59:00 PM PDT, N44° 27.106', W122°32.803'

Cast is GP21, bottom depth is 79m, cast depth is 78m. Offset time is 1:14 for XOTD # 55, file X055-1. Secci depth is 7.0m. Fluorometer and Temp channel are swapped!! Temperature data is no good for the up cast.

6:24:06 PM PDT, N44° 27.106', W122°32.803'

Cast is GP22, bottom depth is 79m, cast aborted, data N.G. not plotted. Offset time is 1:14 for XOTD # 55, file X055-2. Secci depth is 7.0m. Fluorometer and Temp channel are swapped!!

6:32:15 PM PDT, N44° 27.106', W122°32.803'

Cast is GP23, bottom depth is 83m, cast depth is 82m. Offset time is 1:13 for XOTD # 55, file X055-3. Secci depth is 6.5m. Fluorometer and Temp channel are swapped!! Temp still looks bad, will change to the slow temperature probe for tomorrow's work.

6:52 PM PDT, N44° 27.106', W122°32.803'

Drop 15, XOTD # 27, file X027-5, bottom depth is 82m. Deployed with 15 LB test fish line attached to XOTD and wire from surface spool. Fish line not long enough - probe did not reach the bottom!!

7:10 PM PDT, N44° 27.106', W122°32.803'

Drop 16, XOTD # 27, file X027-6, bottom depth is 82m. Added a length of 12 LB test fish line and deployed with line attached to XOTD and wire from surface spool.

N44° 27.106', W122°32.803'

Drop 17, XOTD # 27, file X027-7, bottom depth is 83.4 meters. Free drop - no fish line - lost probe. Drop rate was 6 m/sec. Plot shows only LSS and XOD so that the drop rate can easily be evaluated by matching profile features. Start time was reliable allowing accurate determination of time to bottom and as the data shows bottom depths compare very well. The data shows that the decent rate was higher at the start than at the end of the profile.

October 4, 1993

All cast this day are at Foster reservoir, log boom near the dam, N44° 24.903',W122° 40.134'. Note: The casts today will be done by lowering the optical instruments much slower for two reasons, the depth is only 18.5 meters and the AC 2626 slow response temperature probe is now used to replace the fast response temperature that did not function properly in previous casts.

The configuration for the AXOTD field tests was as follows: The AXOTD probe was connected to XOTD upper spool for surface dereeling. The XOTD upper spool was then connected to the

AXOTD upper spool which is connected to the AXOTD line receiver in the AXOTD surface transmitter which was floating in the water near the boat. The transmitted VHF signal was received by a wide band VHF receiver and sent to the AXOTD processor card installed in a IBM compatible personal computer.

12:14:00 PM PDT, N44° 24.903', W122°40.134'

Cast is FR24, bottom depth is 18.5m, cast depth is 17.0m. Offset time .is 1:12 for XOTD # 55, file X055-4. Secci depth is 6.9m. Low Battery 12 VDC

12:40 PM PDT, N44° 24.903', W122°40.134'

Drop 18, AXO48_5, STD free drop surface dereel.

12:50 PM PDT, N44° 24.903', W122°40.134'.

Drop 19, AXO48_6, STD free drop, surface dereel. Wire from previous drop now adds drag to probe. False start - sample time from 0.033 seconds to 0.557 seconds deleted and then data did not start again until 154.436 seconds.

12:55 PM PDT, N44° 24.903', W122°40.134'

Drop 20, AXO48_7, STD free drop, surface dereel. Bundle of wire Thermistor bent.

1:10 PM PDT, N44° 24.903', W122°40.134'

Drop 21, AXO48_8, STD free drop, surface dereel. Bundle of wire. Thermistor covered with tape 1/16th hole. False start - Data from 0.066 seconds to 2.785 seconds was deleted.

1:20 PM PDT, N44° 24.903', W122°40.134'

Drop 22, AXO48_9, STD free drop, surface dereel. Bundle of wire Thermistor bent. Thermistor covered with tape 1/16th hole. False start - Data from 0.098 seconds to 1.475 seconds was deleted.

1:45:00 PM PDT, N44° 24.903', W122°40.134'

Cast is FR25, bottom depth is 18.5m, cast depth is 17.2m. Offset time is 1:00 for XOTD # 55, file X055-5. Surface temperature, 17.1 °C. New slow response AC2626 probe, Secci depth is 6.9m.

2:00 PM PDT, N44° 24.903', W122°40.134'

Drop 23, AXO48_10, STD free drop, surface dereel. Bundle of wire. Thermistor covered with tape 1/16th hole. False start - Data from 0.066 seconds to 0.852 seconds was deleted.

14:07 PM PDT, N44° 24.903', W122°40.134'

Drop 24 AXO48_11, STD free drop, surface dereel. Bundle of wire. Thermistor open. False start - Data from 0.033 seconds to 0.688 seconds was deleted.

2:17 PM PDT, N44° 24.903', W122°40.134'

Drop 25, AXO48_12, STD free drop, surface dereel. Bundle of wire. Thermistor open. Flow trip 1/2 inch from optical detector. Start OK.

2:20 PM PDT, N44° 24.903', W122°40.134'

Drop 26, AXO48_13, STD free drop, surface dereel. Bundle of wire. Thermistor open. Flow trip 1/2 inch from optical detector. False start - Data from 0.066 seconds to 0.754 seconds was deleted.

2:28 PM PDT, N44° 24.903', W122°40.134'

Drop 27, AXO48_14, STD free drop, surface dereel. Bundle of wire. Thermistor open. Flow trip 1/2 inch from optical detector. Flow trip 1/2 inch from optical detector. False start - Data from 0.066 seconds to 0.786 seconds was deleted.

2:33 PM PDT, N44° 24.903', W122°40.134'

Drop 28, AXO48_15, STD free drop, surface dereel. Bundle of wire. Thermistor flow hole full of mud when checked at surface. Flow trip 1/2 inch from optical detector. Flow trip 1/2 inch from optical detector. False start - Data from 0.033 seconds to 0.786 seconds was deleted. Temperature data N. G. Temperature data N. G.

2:45:00 PM PDT, N44° 24.903', W122°40.134'

Cast is FR26, bottom depth is 18.5m, cast depth is 17.0m. Offset time is 0:42 for XOTD # 55, file X055-6. Secci depth is 7.0m.

15:00 PM PDT, N44° 24.903', W122°40.134'

Drop 29, AXO48_16, STD free drop, surface dereel. No bundle of wire to drag. Thermistor flow hole full of mud when checked at surface. Flow trip 1/2 inch from optical detector. Start at 0.786 seconds. Temperature data N. G. Bad data point at 2.556 seconds.

15:08 PM PDT, N44° 24.903', W122°40.134'

Drop 30, AXO48_17, STD free drop, surface dereel. No bundle of wire to drag. Thermistor flow hole no mud when checked at surface. Flow trip 1/2 inch from optical detector. False start - Data from 0.066 seconds to 0.524 seconds was deleted.

3:20 PM PDT, N44° 24.903', W122°40.134'

Drop 31, AXO48_18, STD free drop, surface dereel. No bundle of wire to drag. Thermistor flow hole full of mud when checked at surface. No Flow trip. False start - Data from 0.066 seconds to 0.688 seconds was deleted.

3:25 PM PDT, N44° 24.903', W122°40.134'

Drop 32, AXO48_19, STD free drop, surface dereel. No bundle of wire to drag. Thermistor flow hole full of mud when checked at surface. No Flow trip. False start - Data from 23.069 seconds to 27.001 seconds was deleted.

3:33 PM PDT, N44° 24.903', W122°40.134'

Drop 33, AXO48_20, STD free drop, surface dereel. No bundle of wire to drag. Thermistor flow hole full of mud when checked at surface. New flow trip 1 cm from optical detector edge. Lost audio 2.6 sec. No usable data, data not plotted.

6:45 PM PDT, N44° 24.903', W122°40.134'

Drop 34, AXO55_7, STD free drop, surface dereel. No bundle of wire to drag. Thermistor flow hole no mud when checked at surface. No Flow trip. Start OK.

6:53 PM PDT, N44° 24.903', W122°40.134'

Drop 35, AXO55_8, STD free drop, surface dereel. No bundle of wire to drag. Thermistor flow hole no mud when checked at surface. No Flow trip. False start - Data from 0.066 seconds to 1.475 seconds was deleted.

6:58 PM PDT, N44° 24.903', W122°40.134'

Drop 36,. AXO55_9, STD free drop, surface dereel. No bundle of wire to drag. Thermistor flow hole no mud when checked at surface. No Flow trip. Start OK.

7:06 PM PDT, N44° 24.903', W122°40.134'

Drop 37, AXO55_10, STD free drop, surface dereel. No bundle of wire to drag. Thermistor flow hole no mud when checked at surface. Added flow trip 1 cm from optical detector. Dark Outside. False start - Data from 0.098 seconds to 0.786 seconds was deleted.

7:12 PM PDT, N44° 24.903', W122°40.134'

Drop 38, AXO55_11, STD free drop, surface dereel. No bundle of wire to drag. Thermistor flow hole no mud when checked at surface. Added flow trip 1 cm from optical detector. False start - Data from 0.098 seconds to 0.754 seconds was deleted. Transmissometer data N.G., off scale.

7:28:30 PM PDT, N44° 24.903', W122°40.134'

Cast is FR27, bottom depth is 18.5m, cast depth is 17.7m hit bottom. Offset time is 1:30 for XOTD # 48, file X048-21. Secci depth is 7.0m.

7:52 PM PDT, N44° 24.903', W122°40.134'

Drop 39, AXO55_12, STD free drop, surface dereel. No bundle of wire to drag. Added flow trip 1 cm from optical detector. False start - Data from 41.026 seconds to 41.812 seconds was deleted.

7:58 PM PDT, N44° 24.903', W122°40.134'

Drop 40, AXO55_13, STD free drop, surface dereel. No bundle of wire to drag. Thermistor flow hole, no mud when checked at surface. Added flow trip 1 cm from optical detector. False start - Data from 0.033 seconds to 0.786 seconds was deleted.

8:05 PM PDT, N44° 24.903', W122°40.134'

Drop 41, AXO55_14, STD free drop, surface dereel. Broken wire after 2 seconds, no usable data and data not plotted.

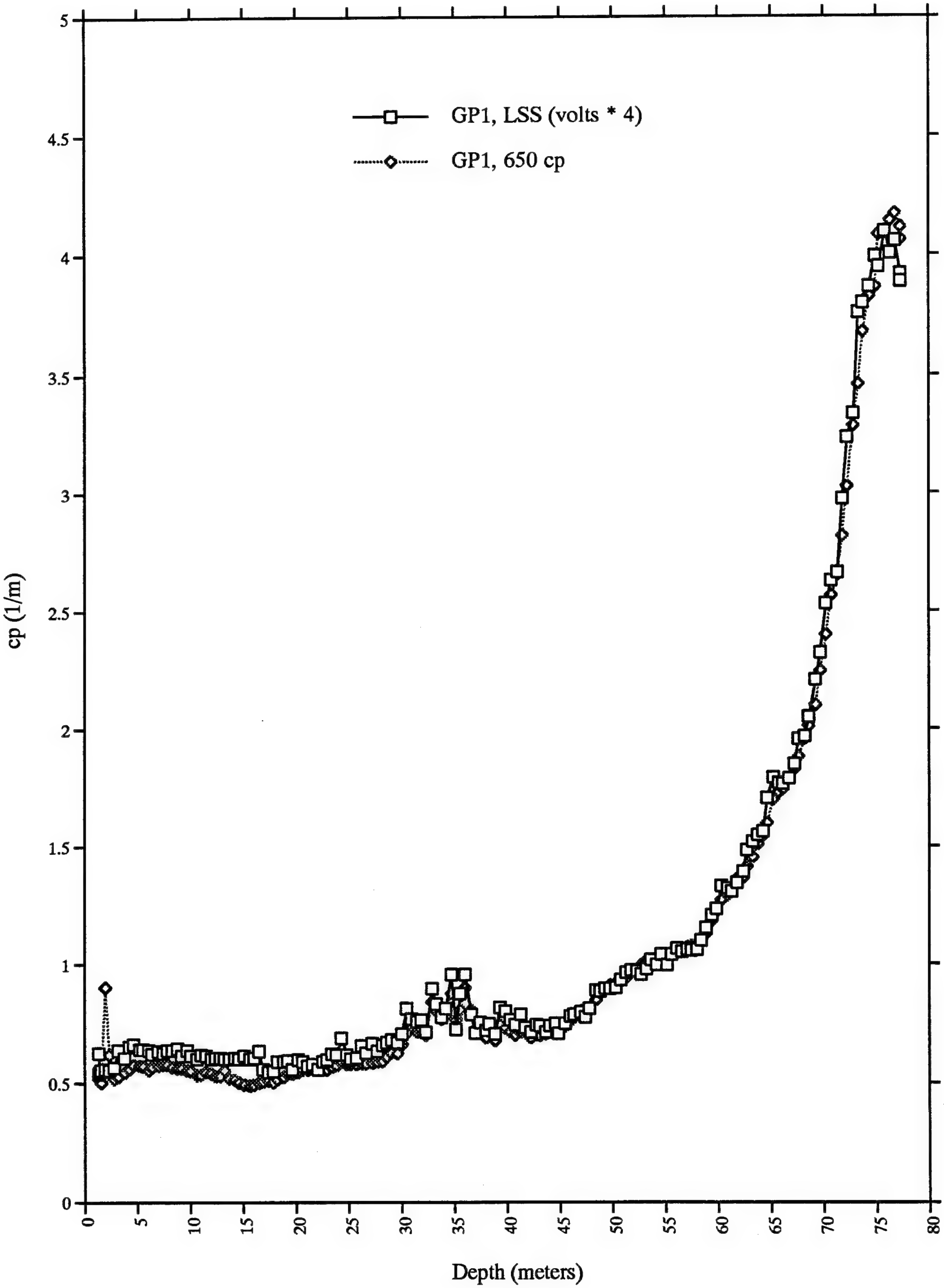
8:26 PM PDT, N44° 24.903', W122°40.134'

Cast is FR28, no AXOTD, bottom depth is 18.5m. Final Cast, field tests complete.

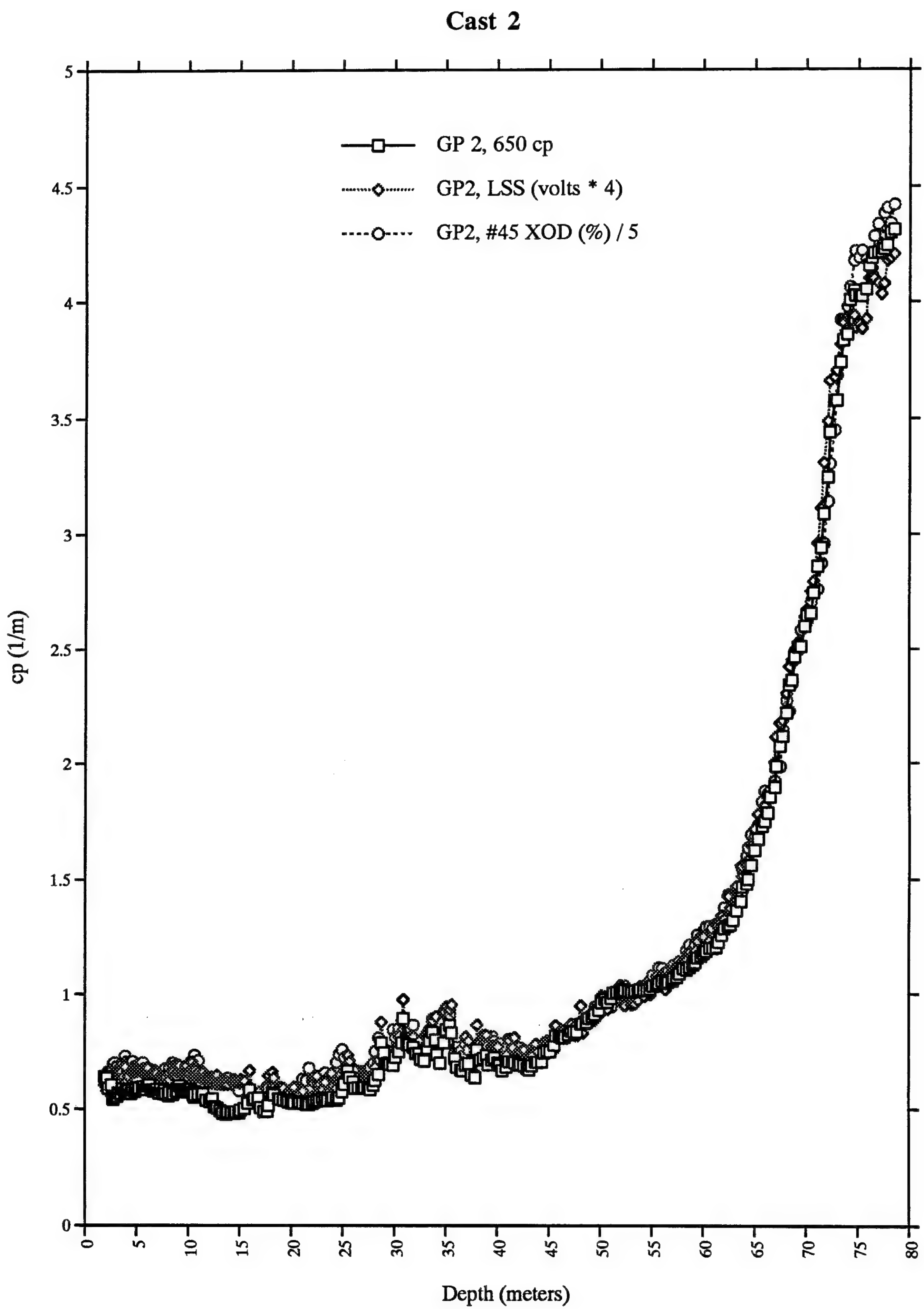
Field Test Data

Casts 1 through 28

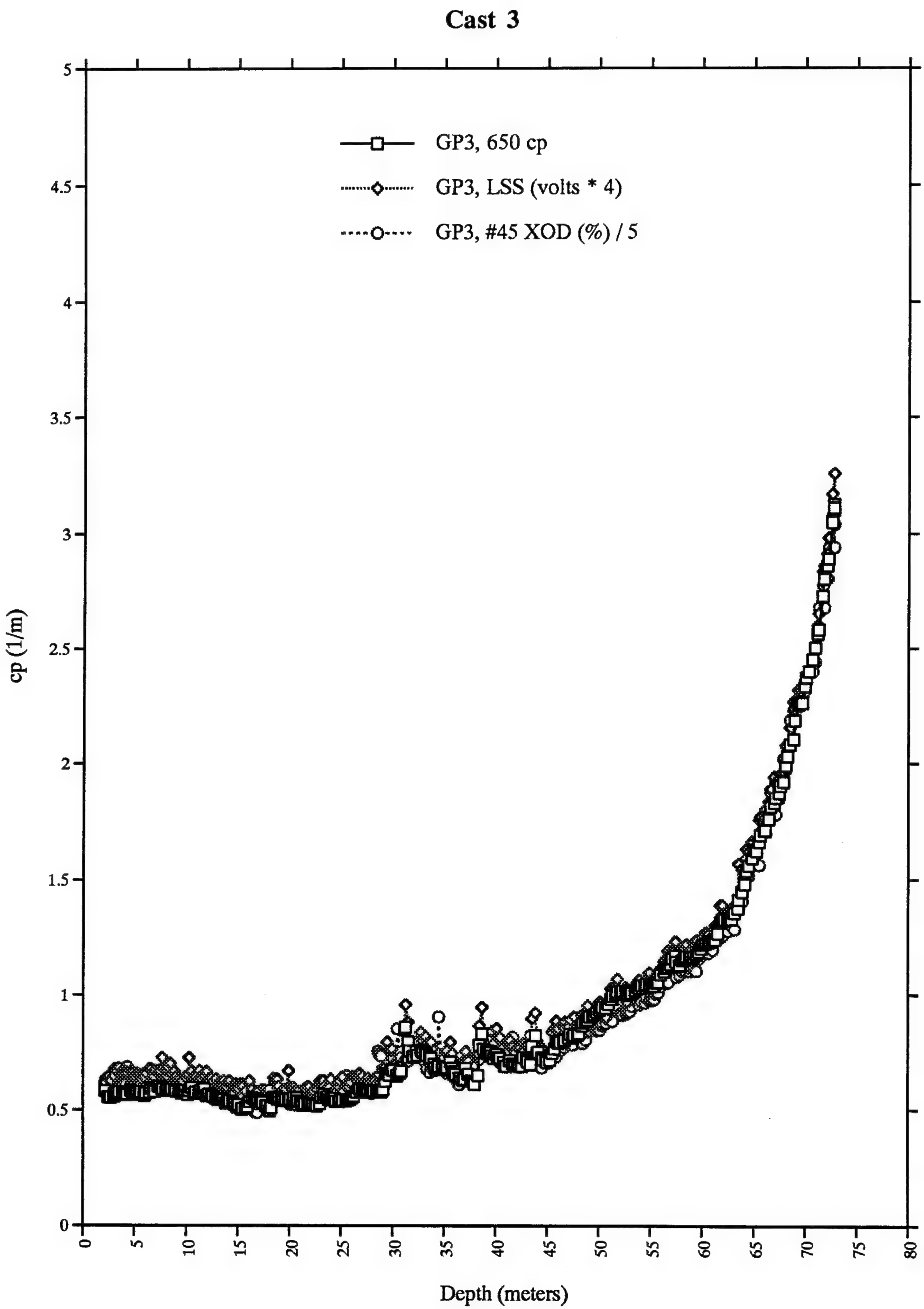
Cast 1

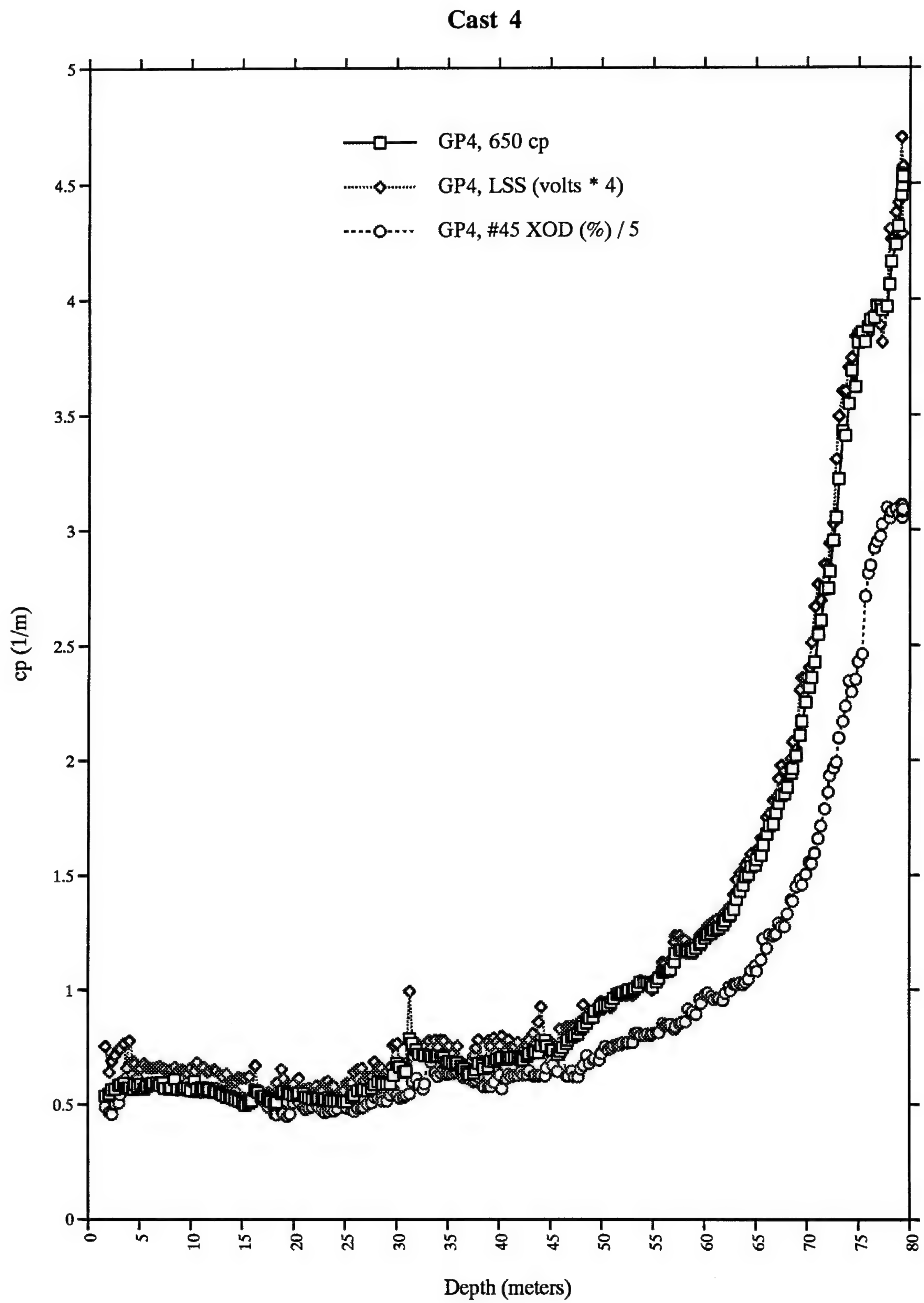


GP1, LSS (volts * 4)
GP1, 650 cp
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

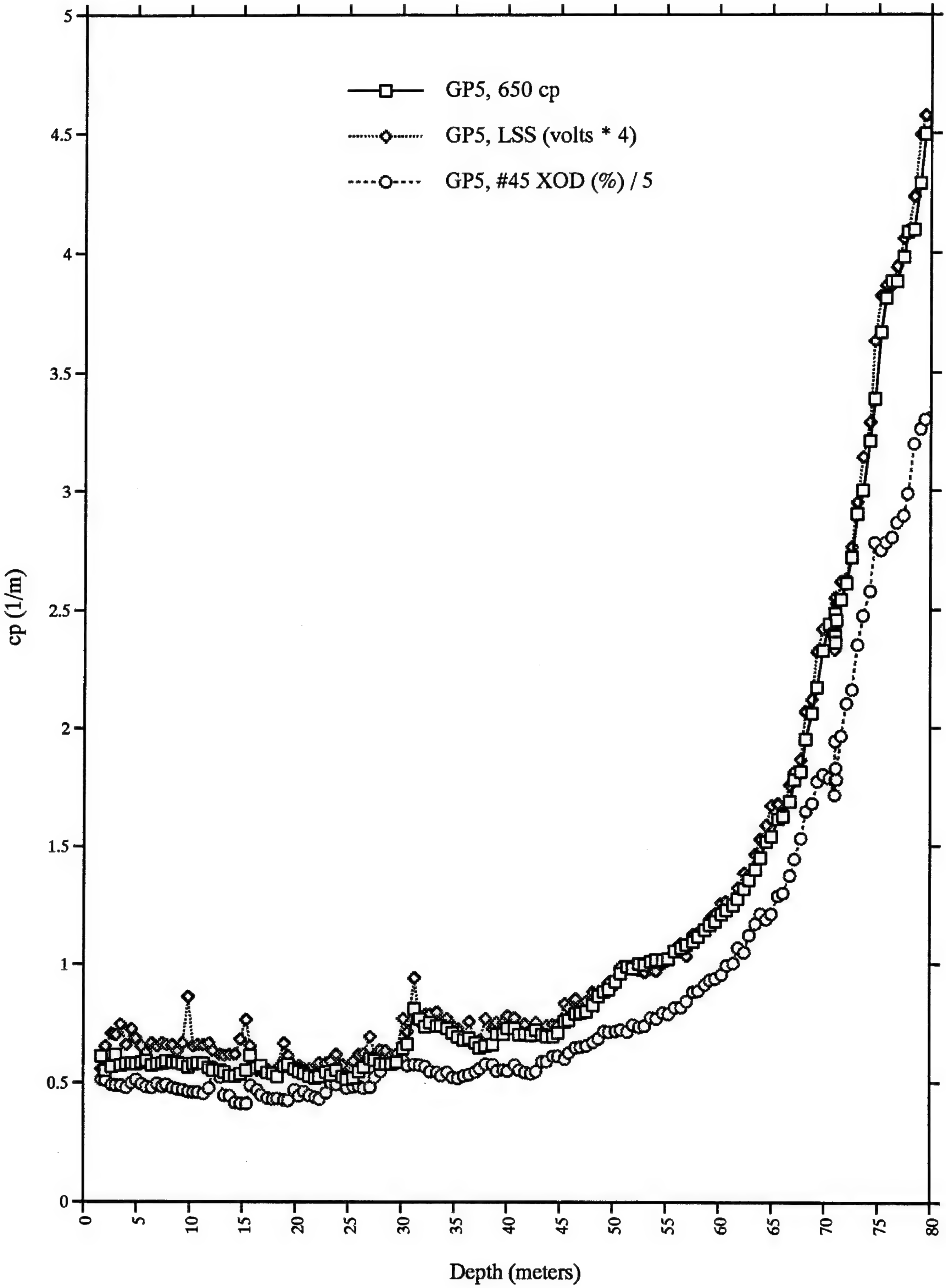


Cast 2
GP 2, 650 cp
GP2, LSS (volts * 4)
GP2, #45 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

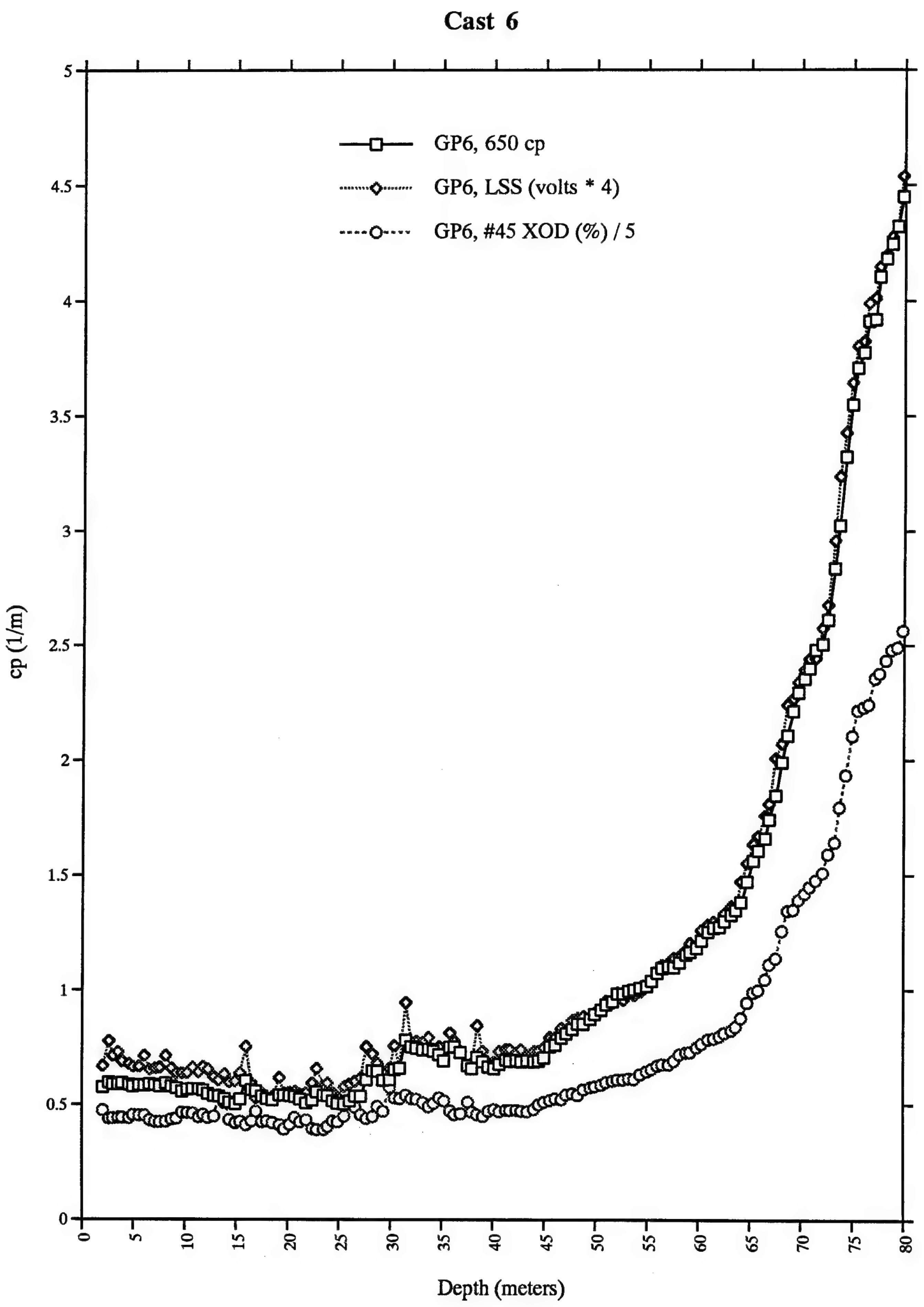

Cast 3
GP3, 650 cp
GP3, LSS (volts * 4)
GP3, #45 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80


Cast 4
GP4, 650 cp
GP4, LSS (volts * 4)
GP4, #45 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

Cast 5

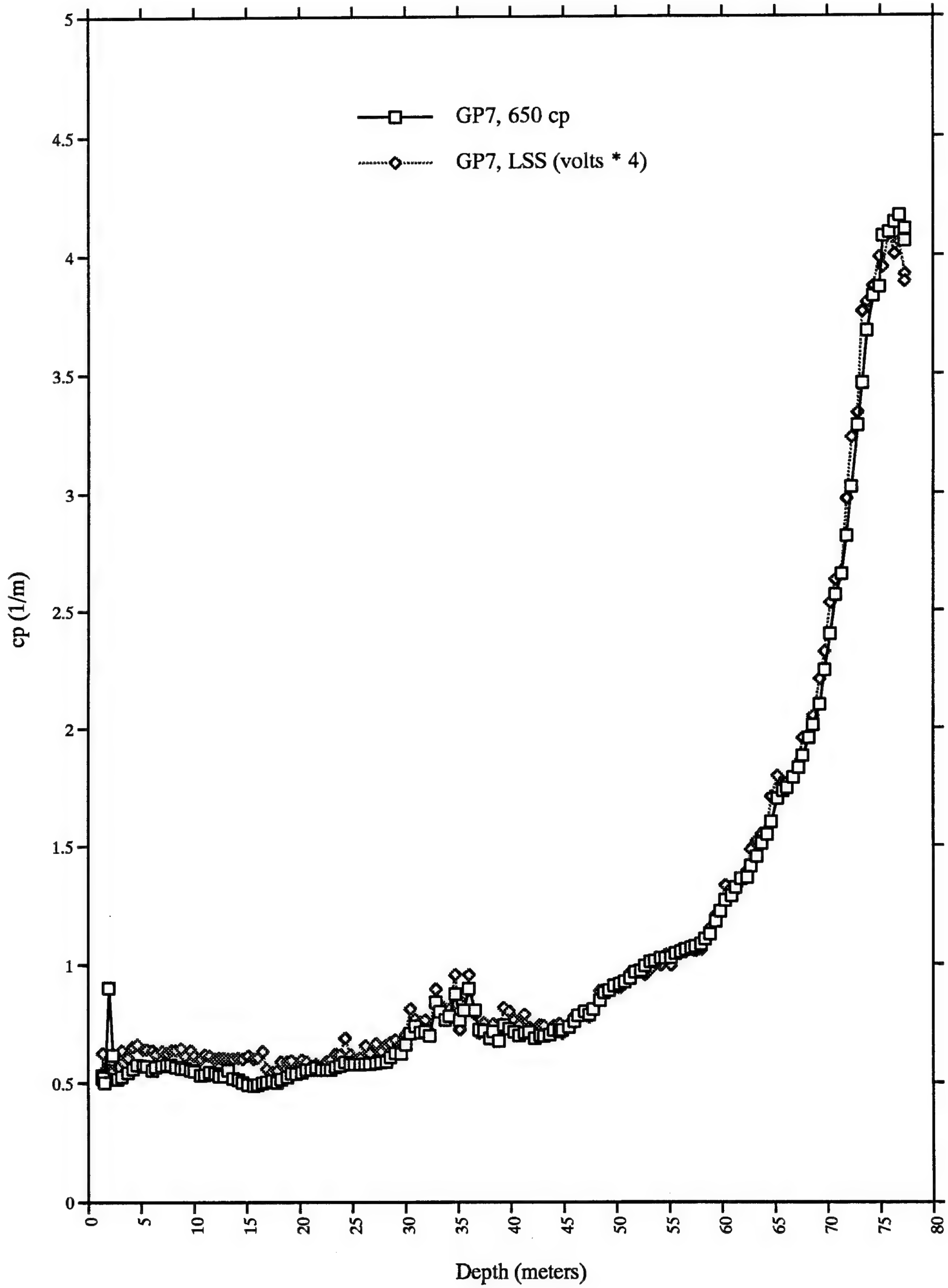


GP5, 650 cp
GP5, LSS (volts * 4)
GP5, #45 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80



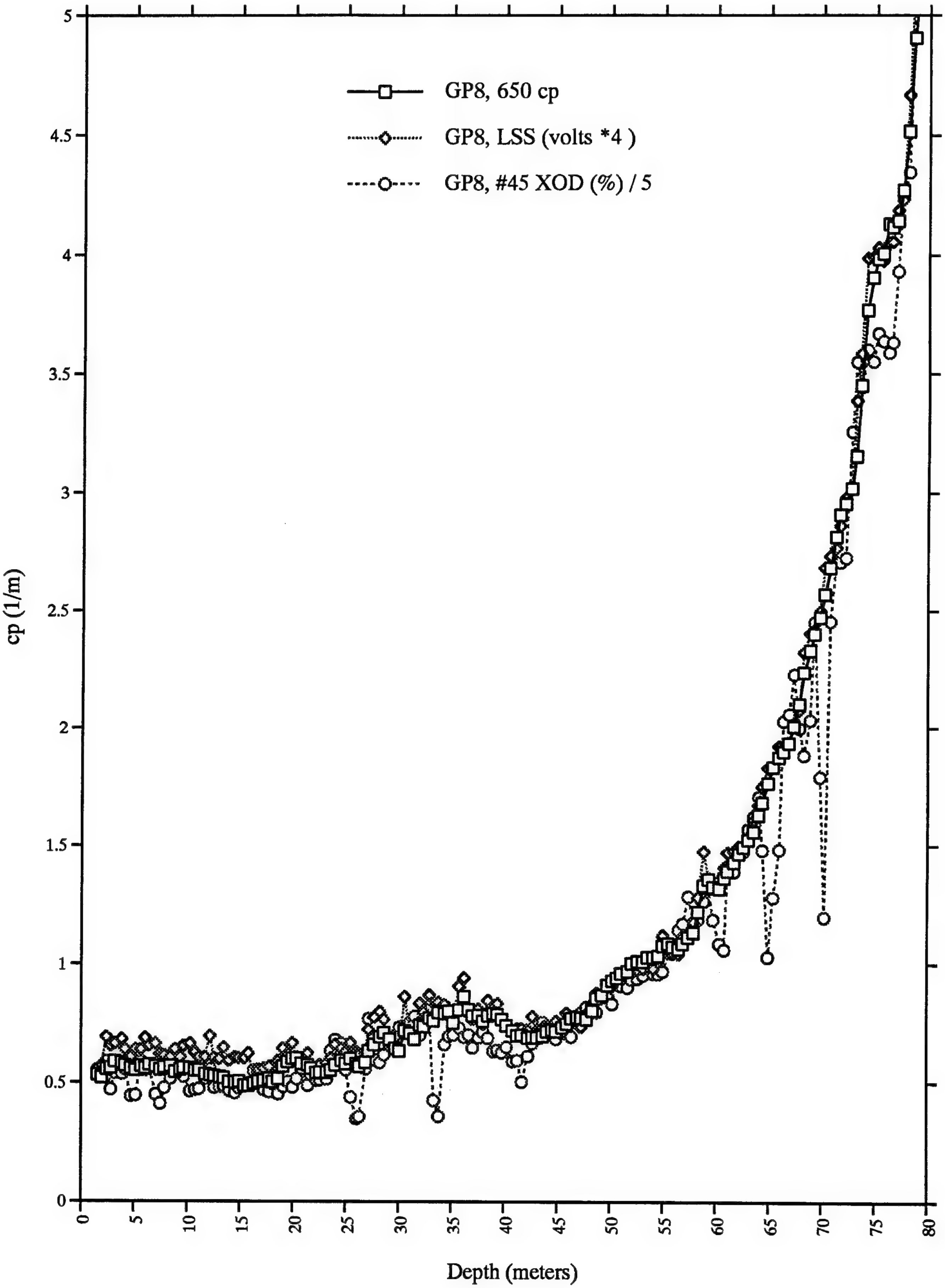
Cast 6
GP6, 650 cp
GP6, LSS (volts * 4)
GP6, #45 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

Cast 7



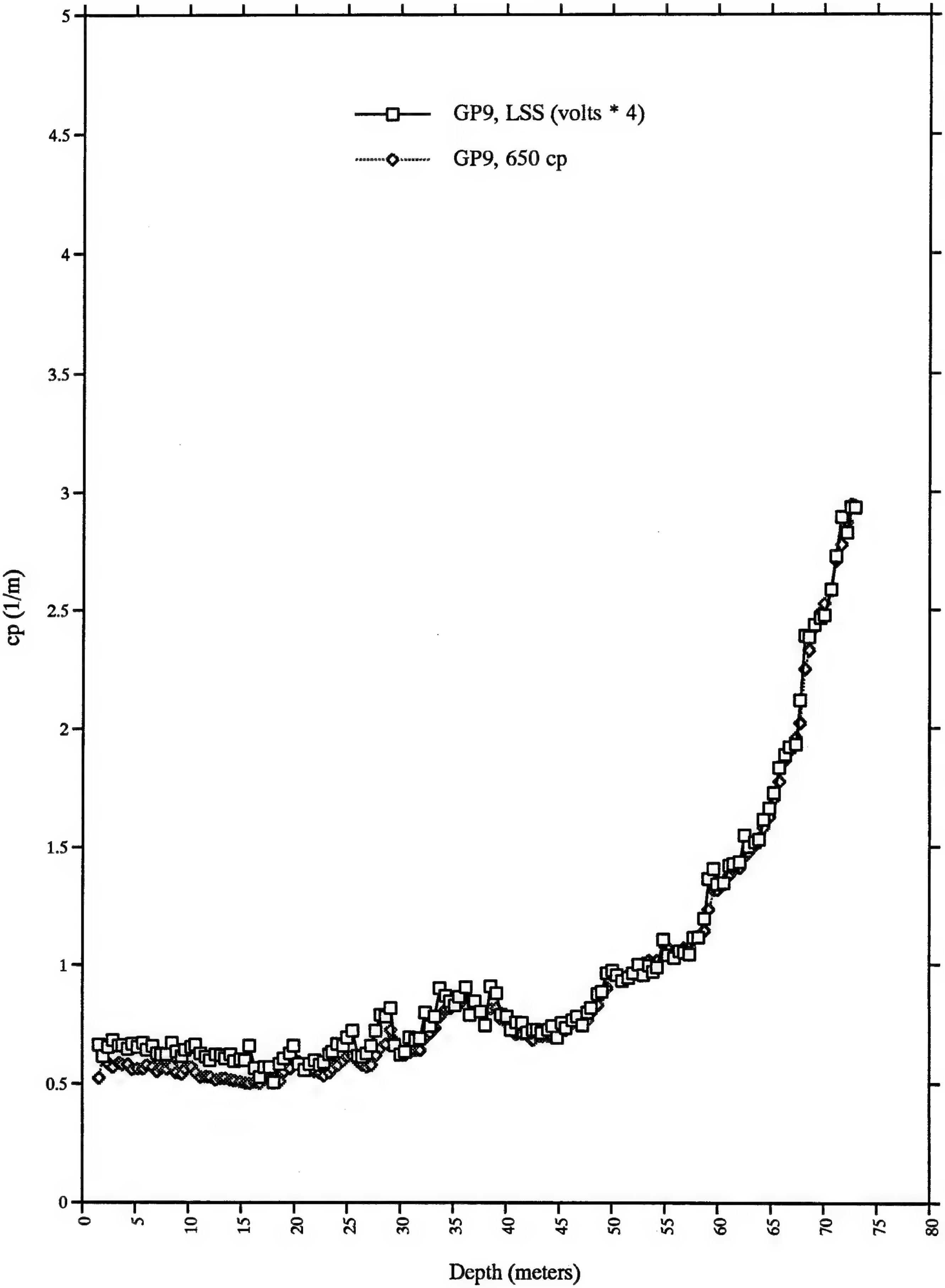
GP7, 650 cp
GP7, LSS (volts * 4)
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

Cast 8

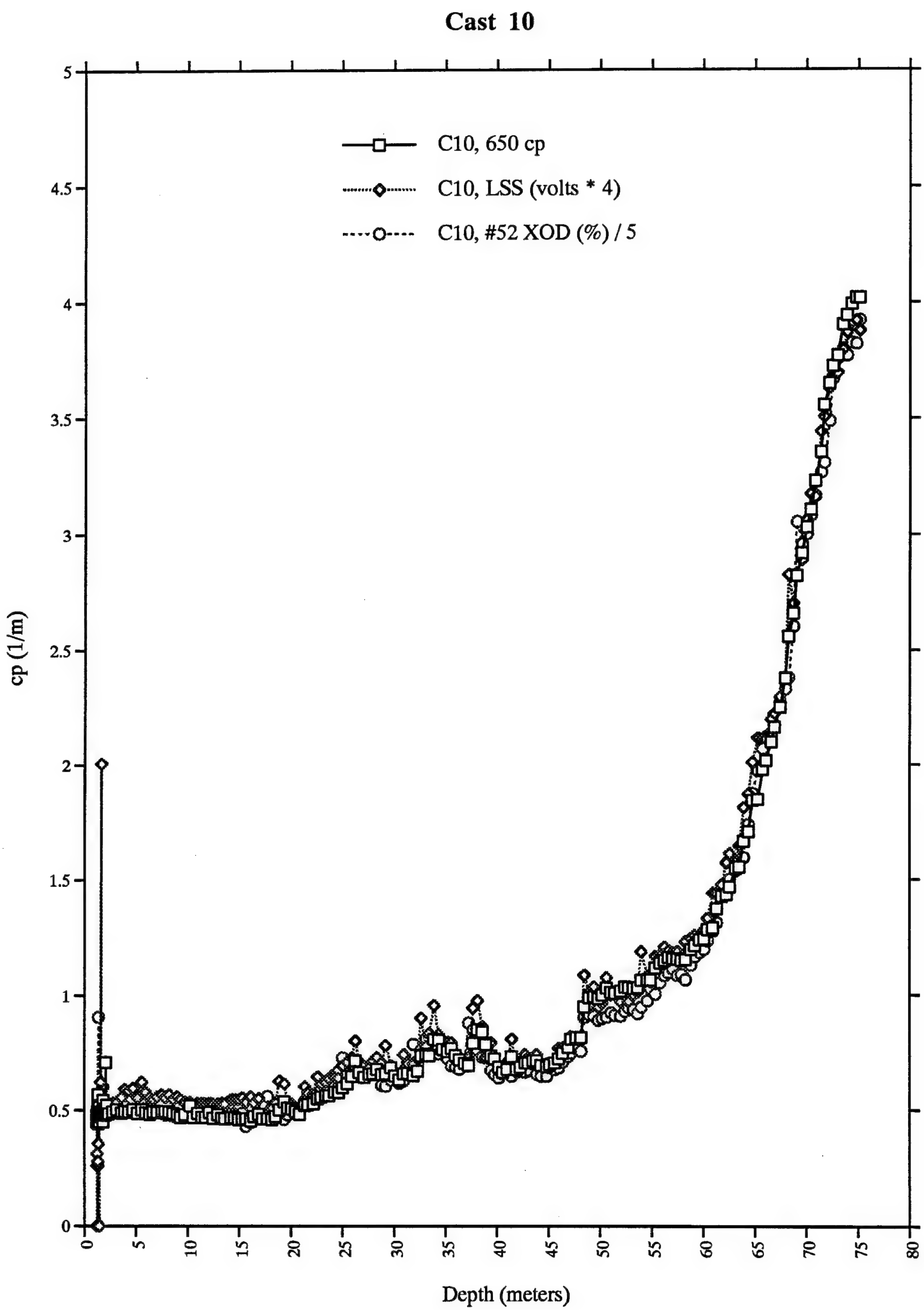


GP8, 650 cp
GP8, LSS (volts *4)
GP8, #45 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

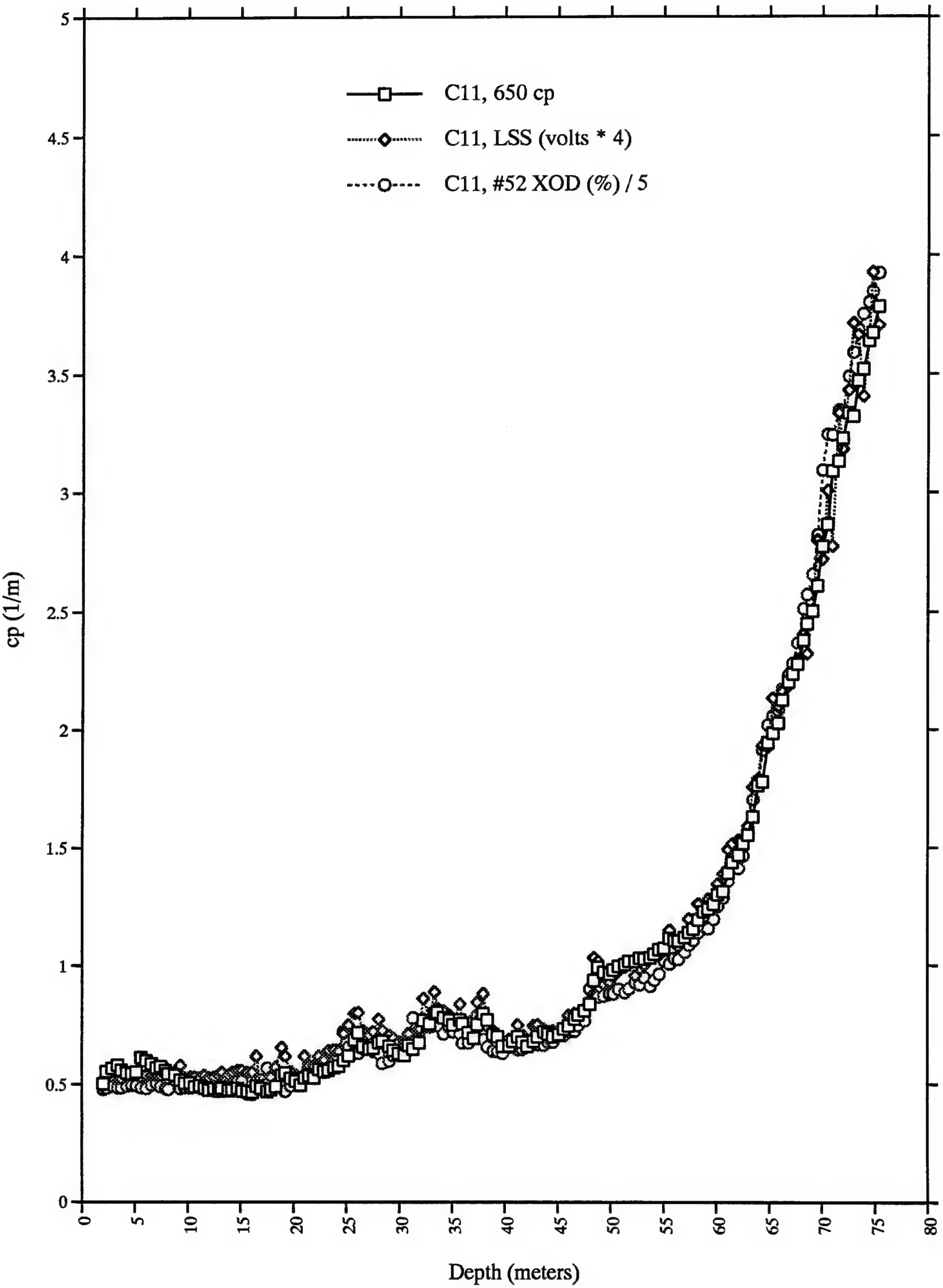
Cast 9



GP9, LSS (volts * 4)
GP9, 650 cp
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

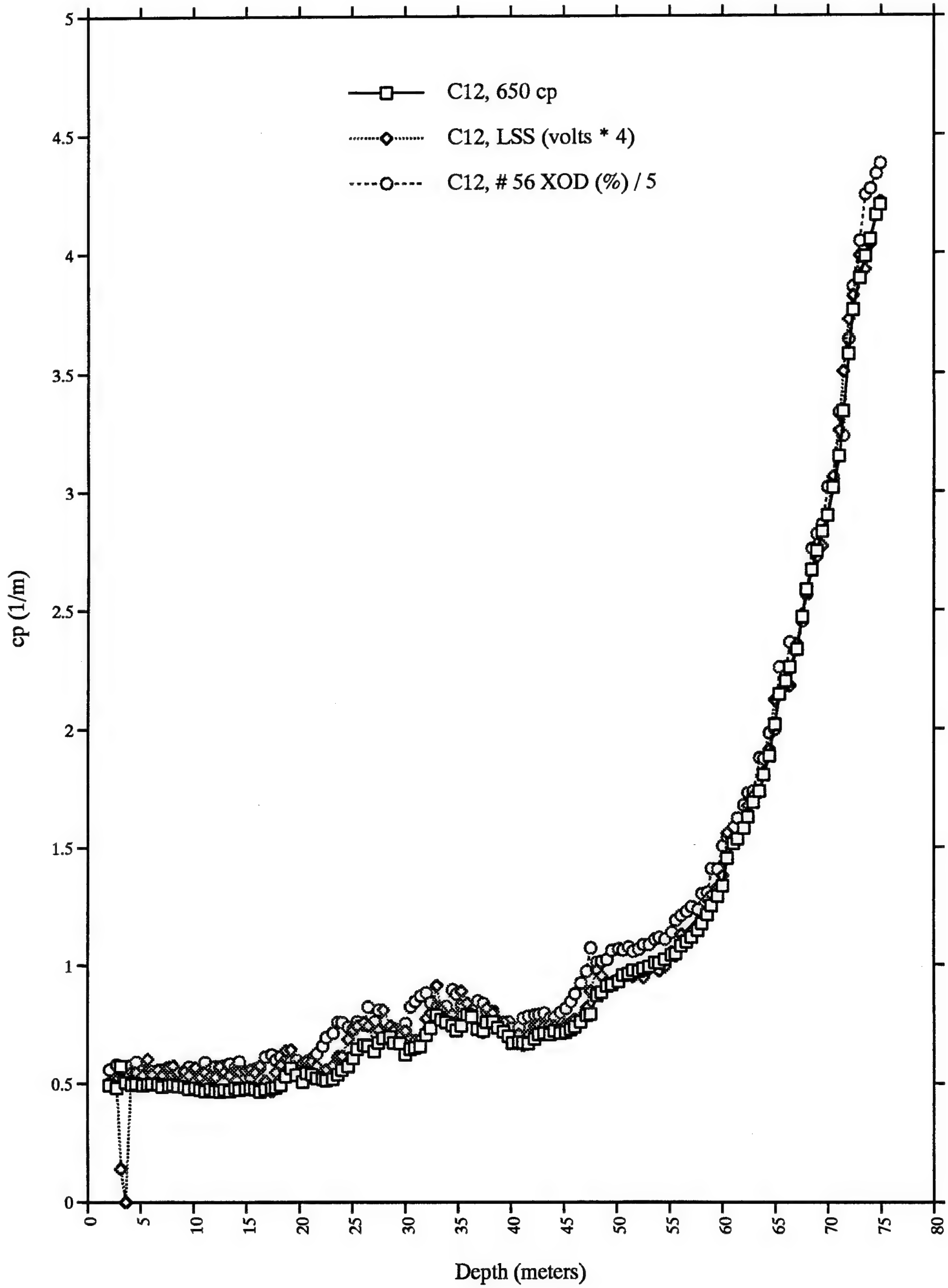

Cast 10
C10, 650 cp
C10, LSS (volts * 4)
C10, #52 XOD (%) / 5
cp (1/m)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
Depth (meters)

Cast 11



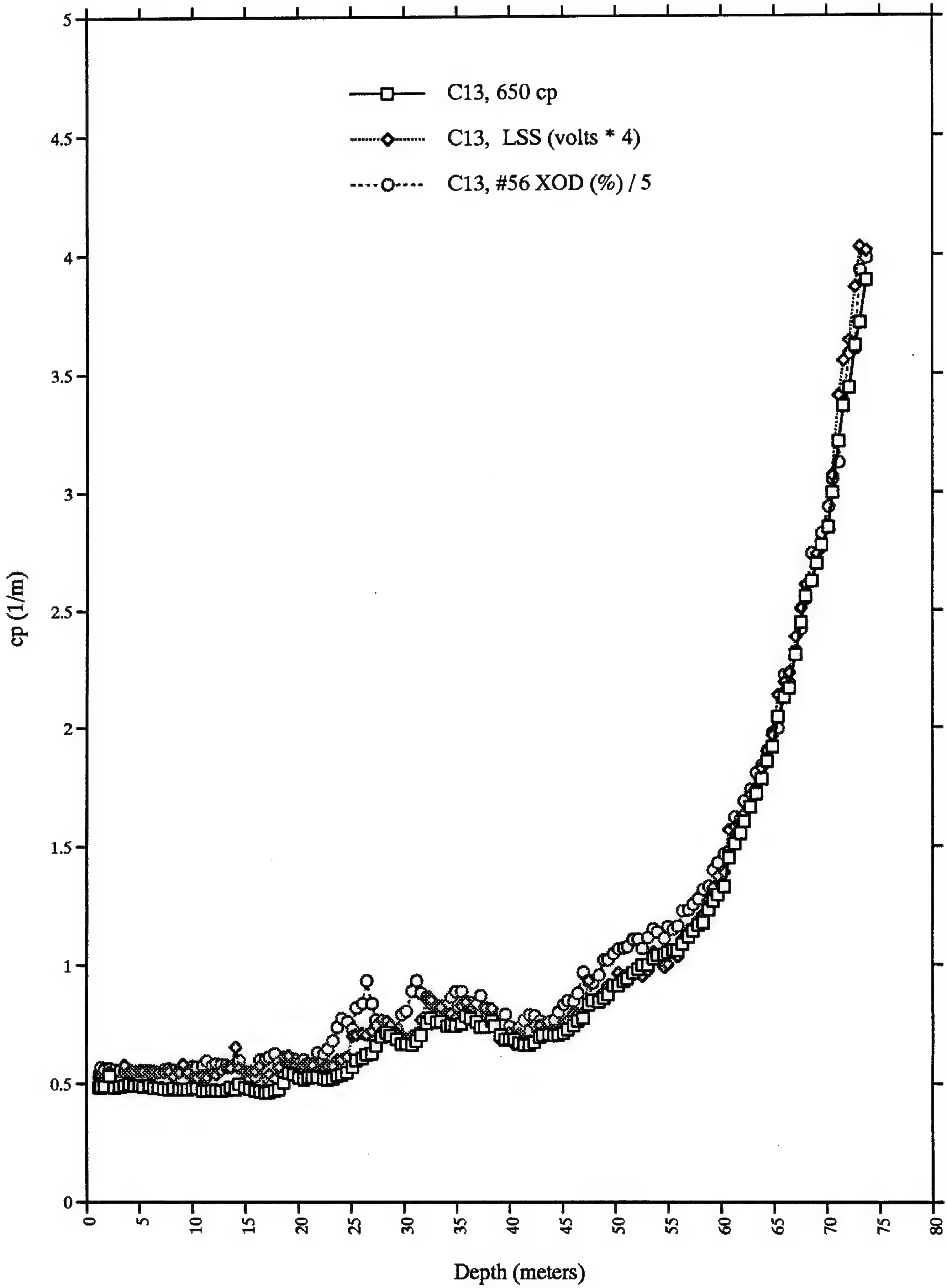
C11, 650 cp
C11, LSS (volts * 4)
C11, #52 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

Cast 12

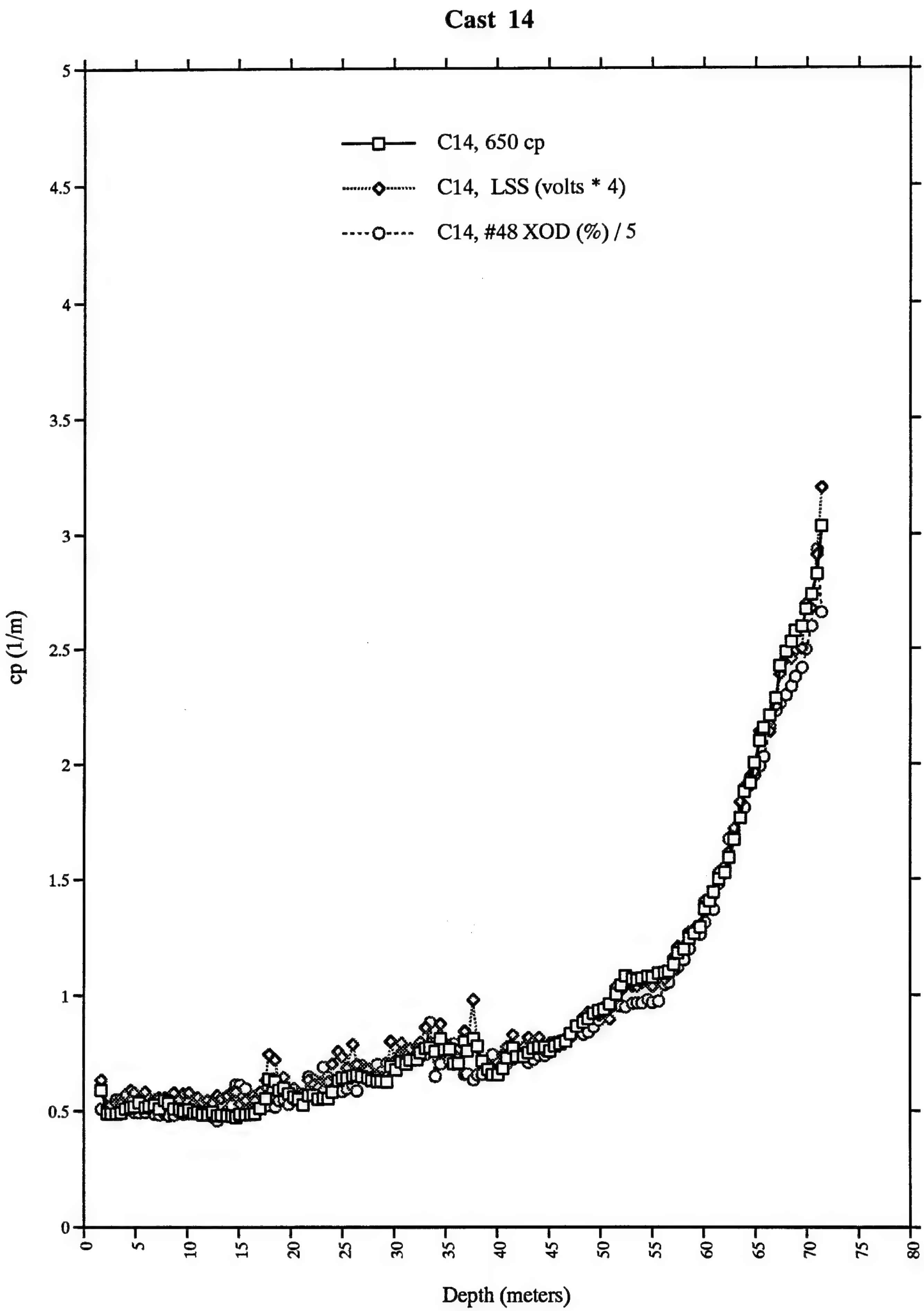


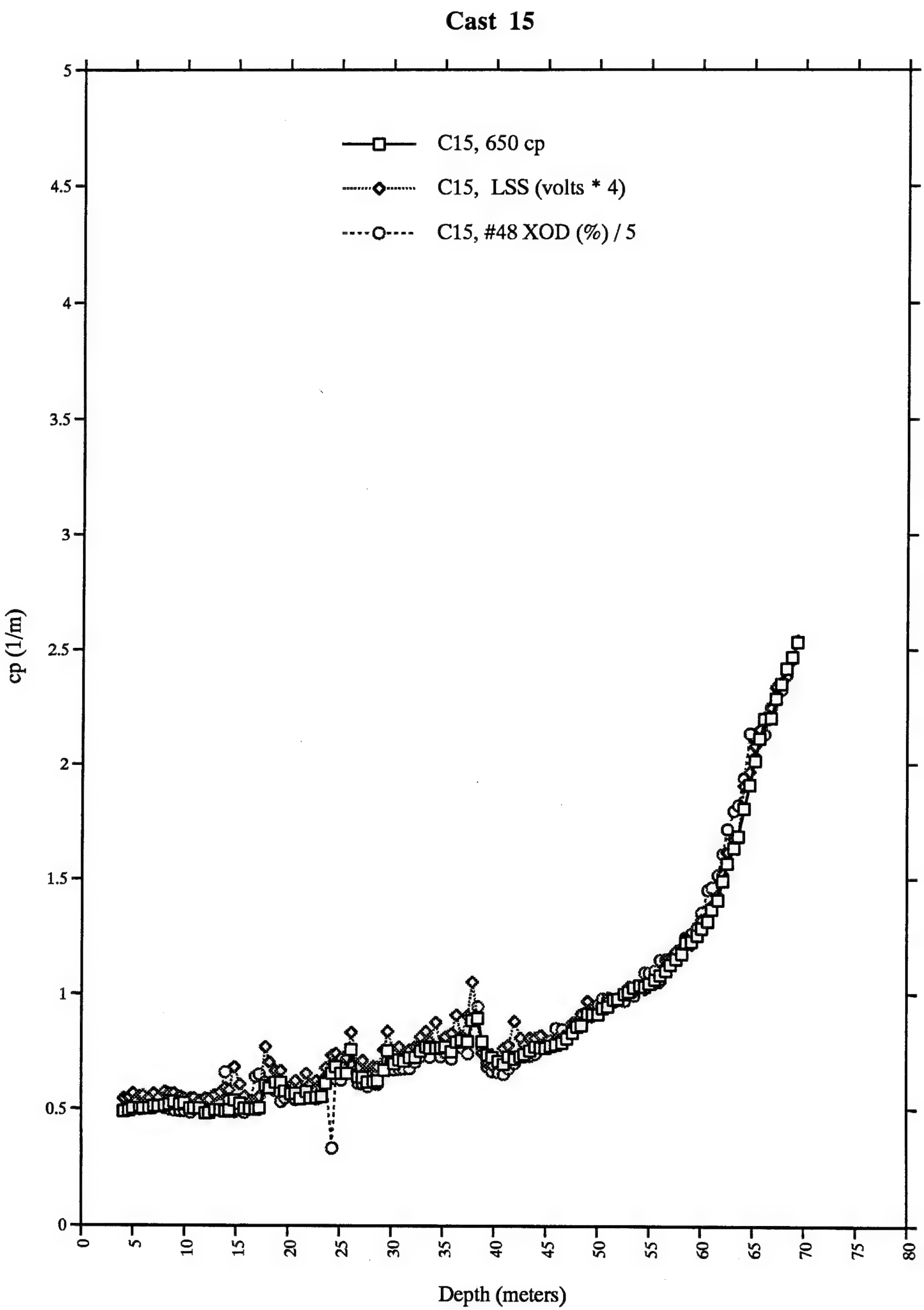
C12, 650 cp
C12, LSS (volts * 4)
C12, # 56 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

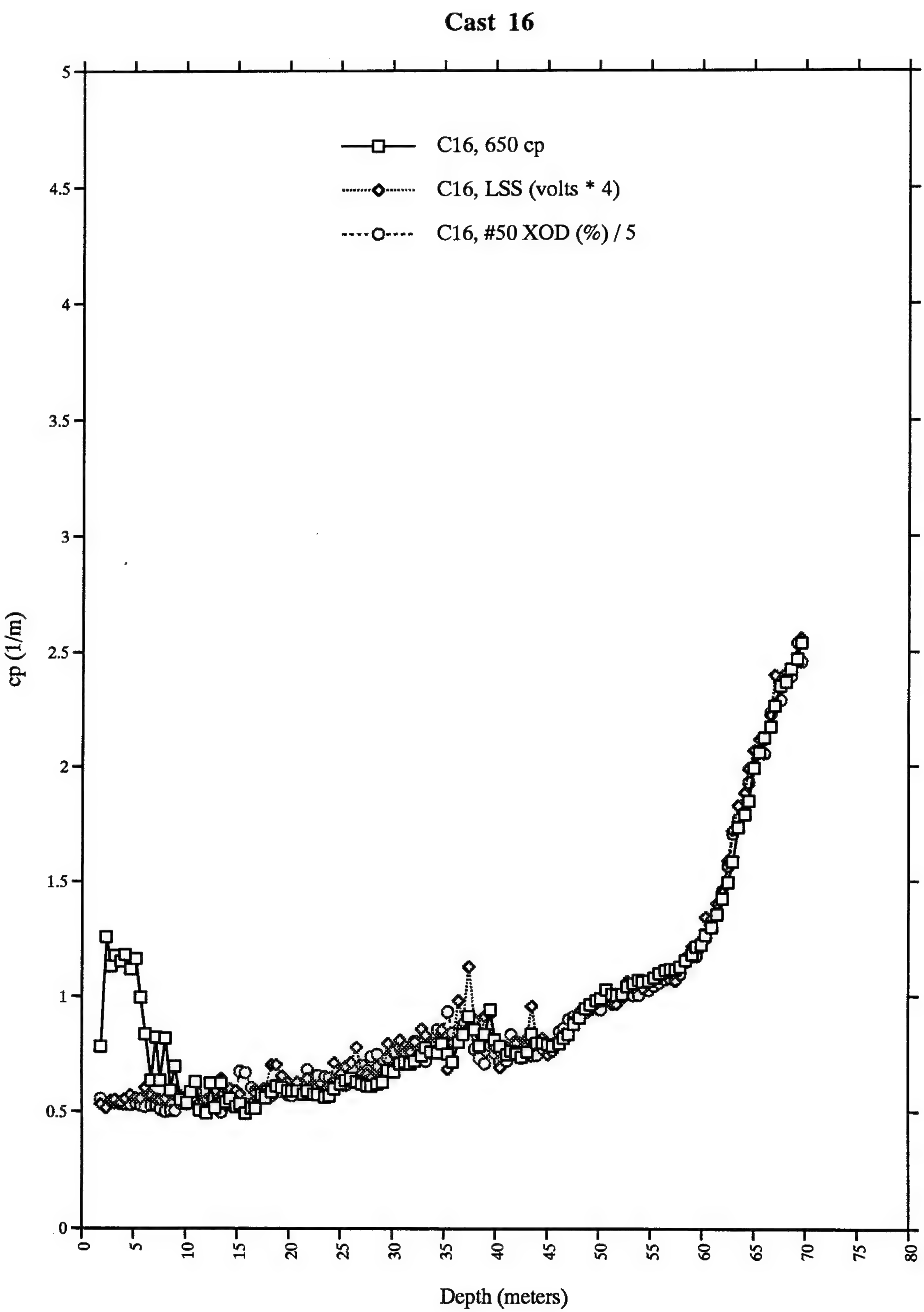
Cast 13



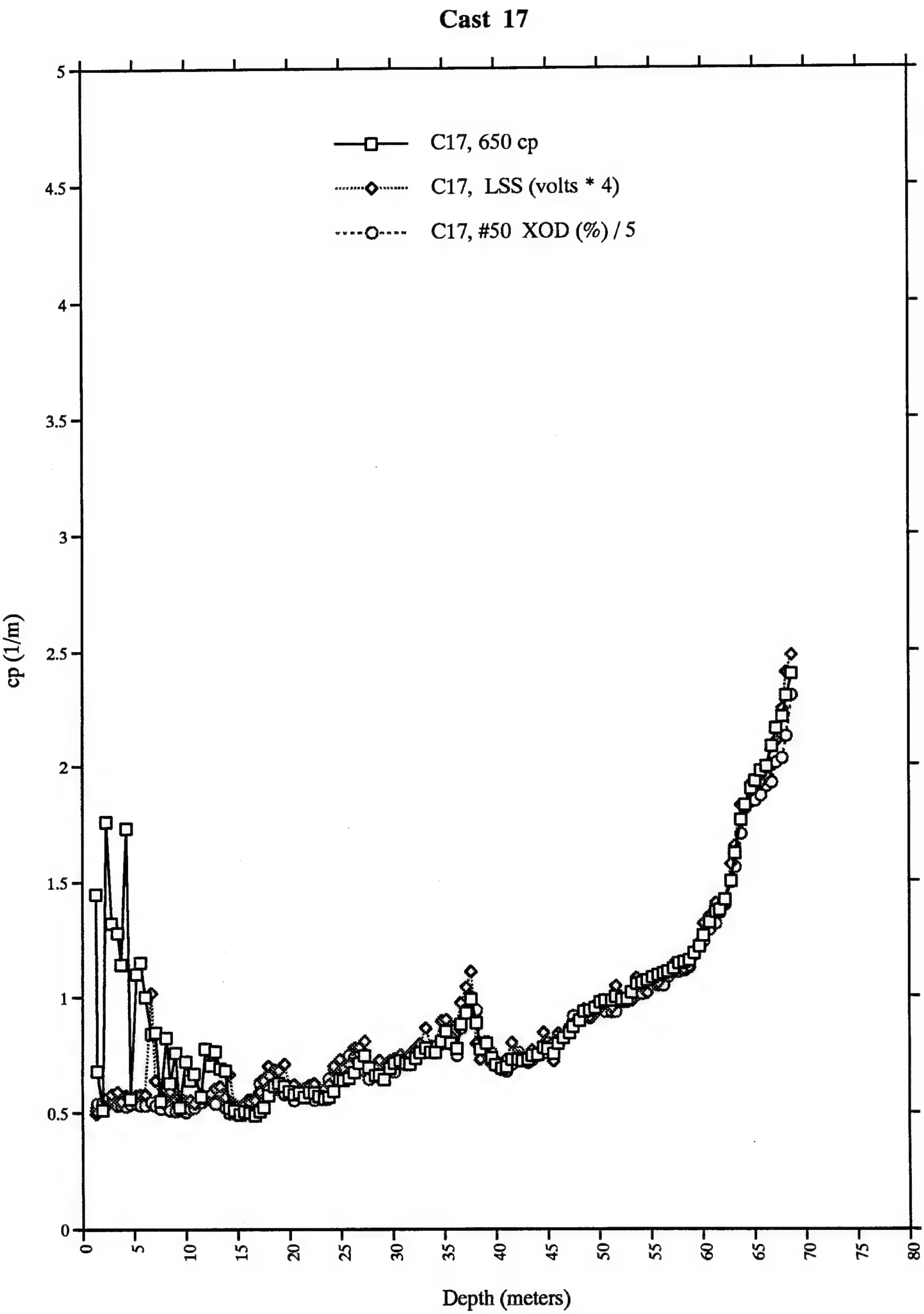
C13, 650 cp
C13, LSS (volts * 4)
C13, #56 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

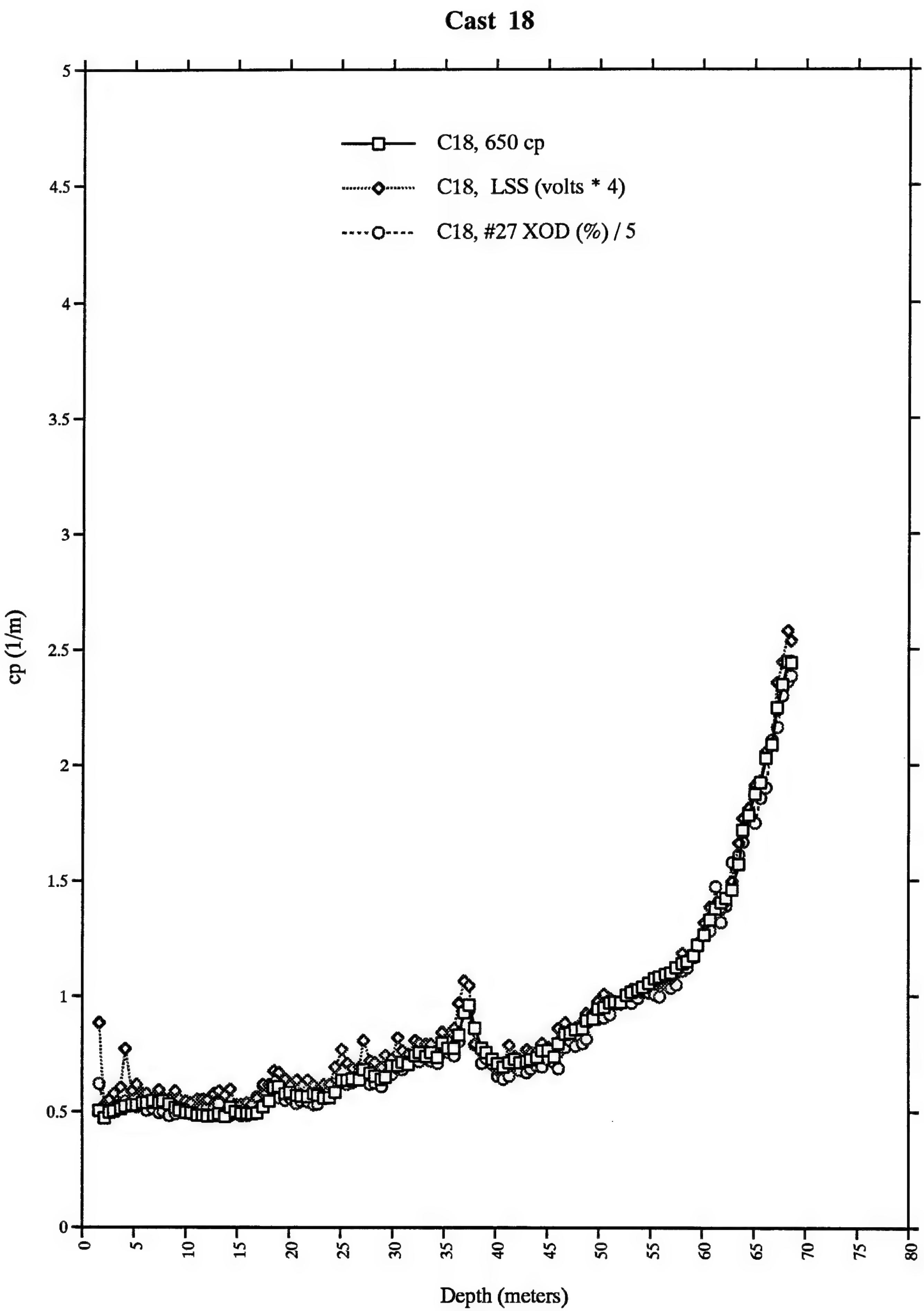

Cast 14
C14, 650 cp
C14, LSS (volts * 4)
C14, #48 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80


Cast 15
C15, 650 cp
C15, LSS (volts * 4)
C15, #48 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

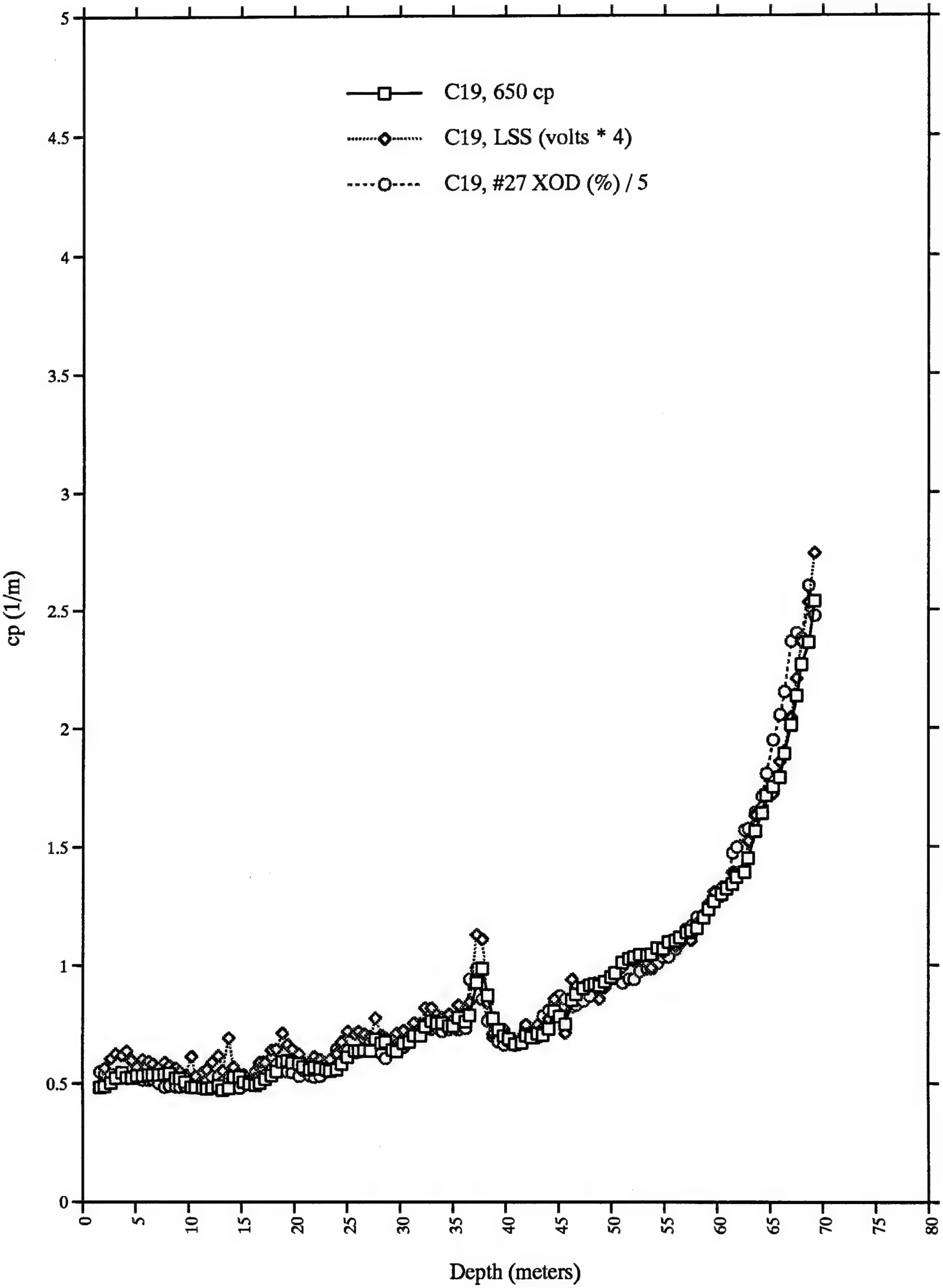


Cast 16
C16, 650 cp
C16, LSS (volts * 4)
C16, #50 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80


Cast 17
C17, 650 cp
C17, LSS (volts * 4)
C17, #50 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

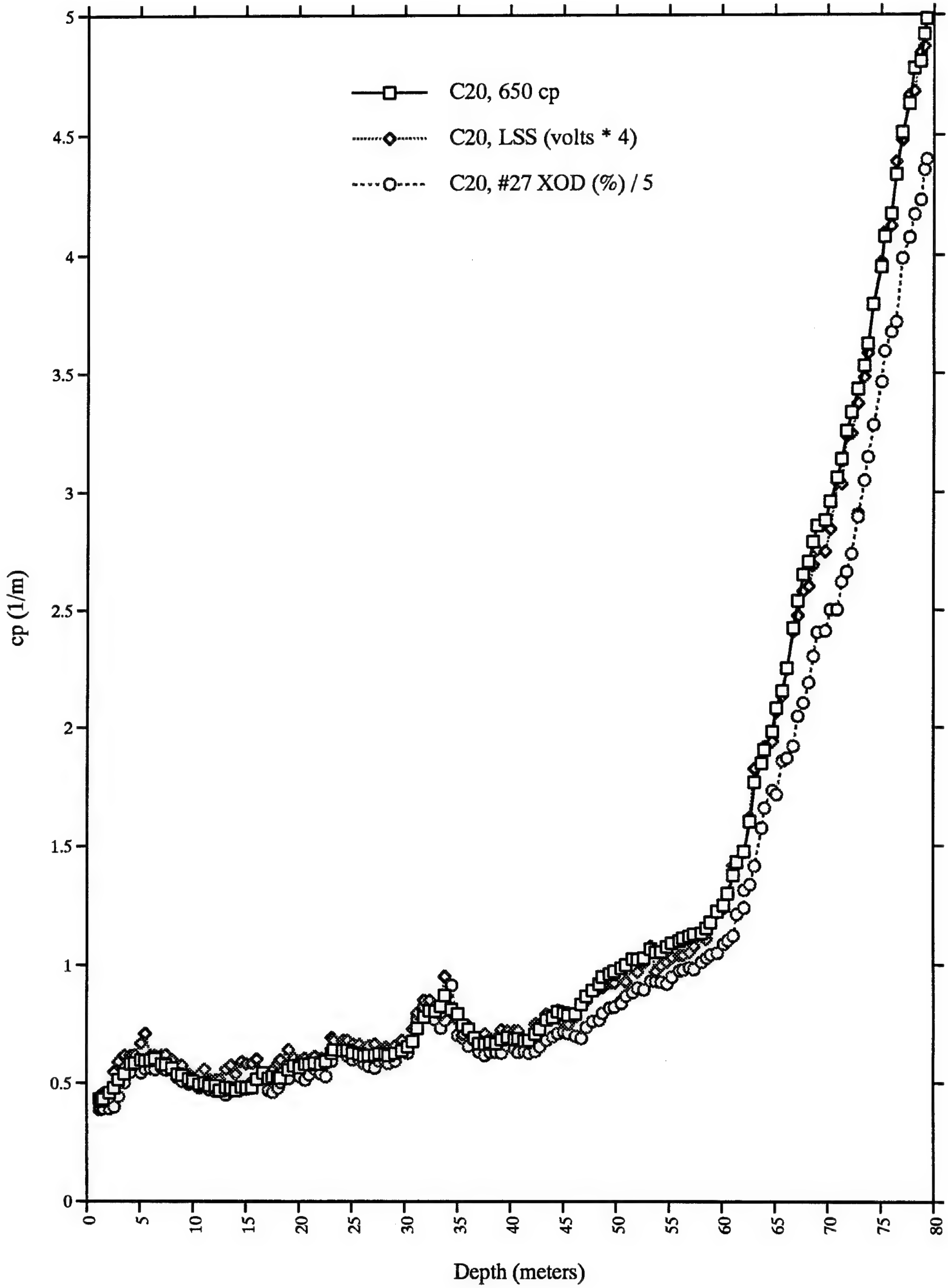

Cast 18
C18, 650 cp
C18, LSS (volts * 4)
C18, #27 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

Cast 19



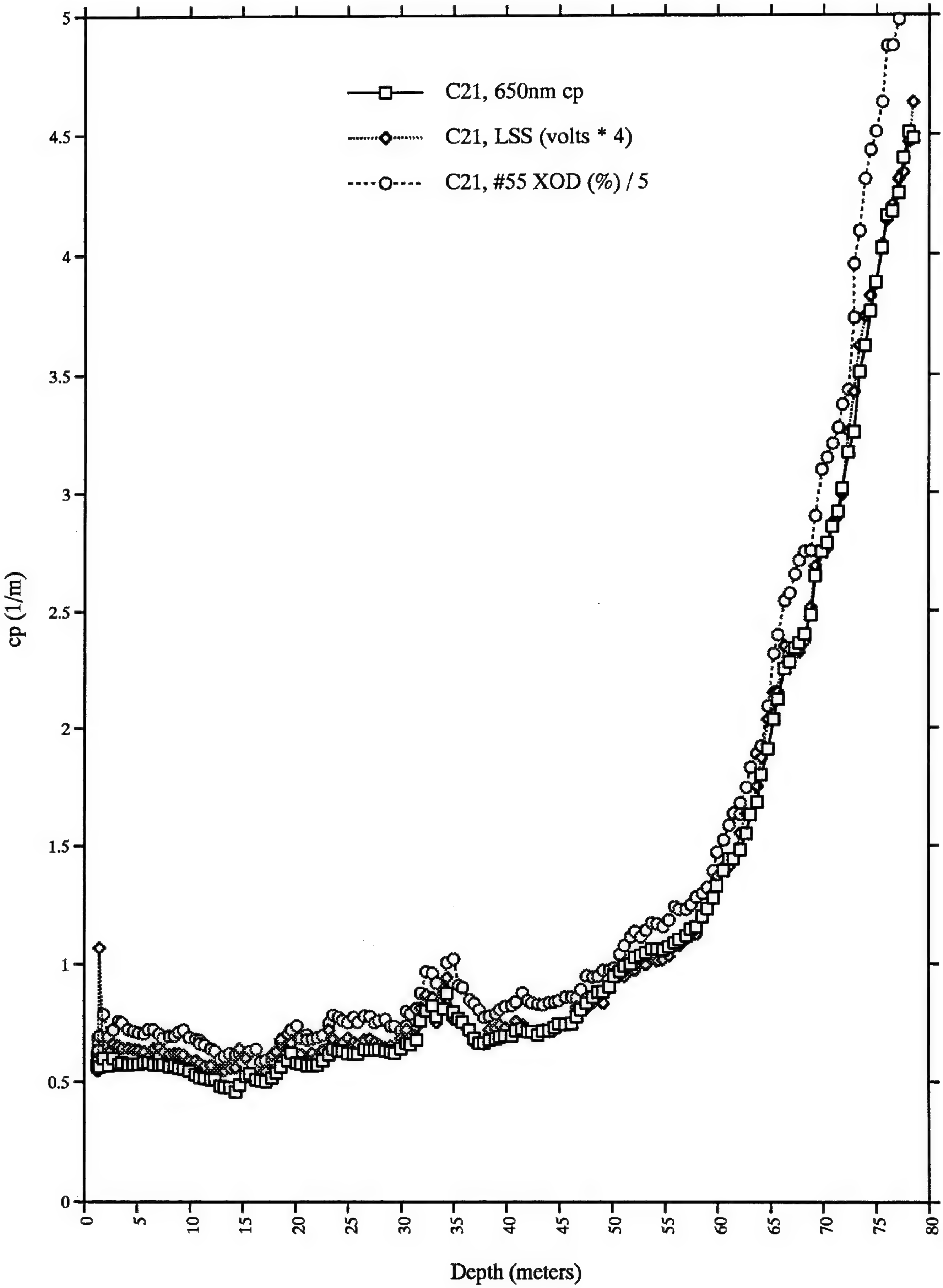
C19, 650 cp
C19, LSS (volts * 4)
C19, #27 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

Cast 20



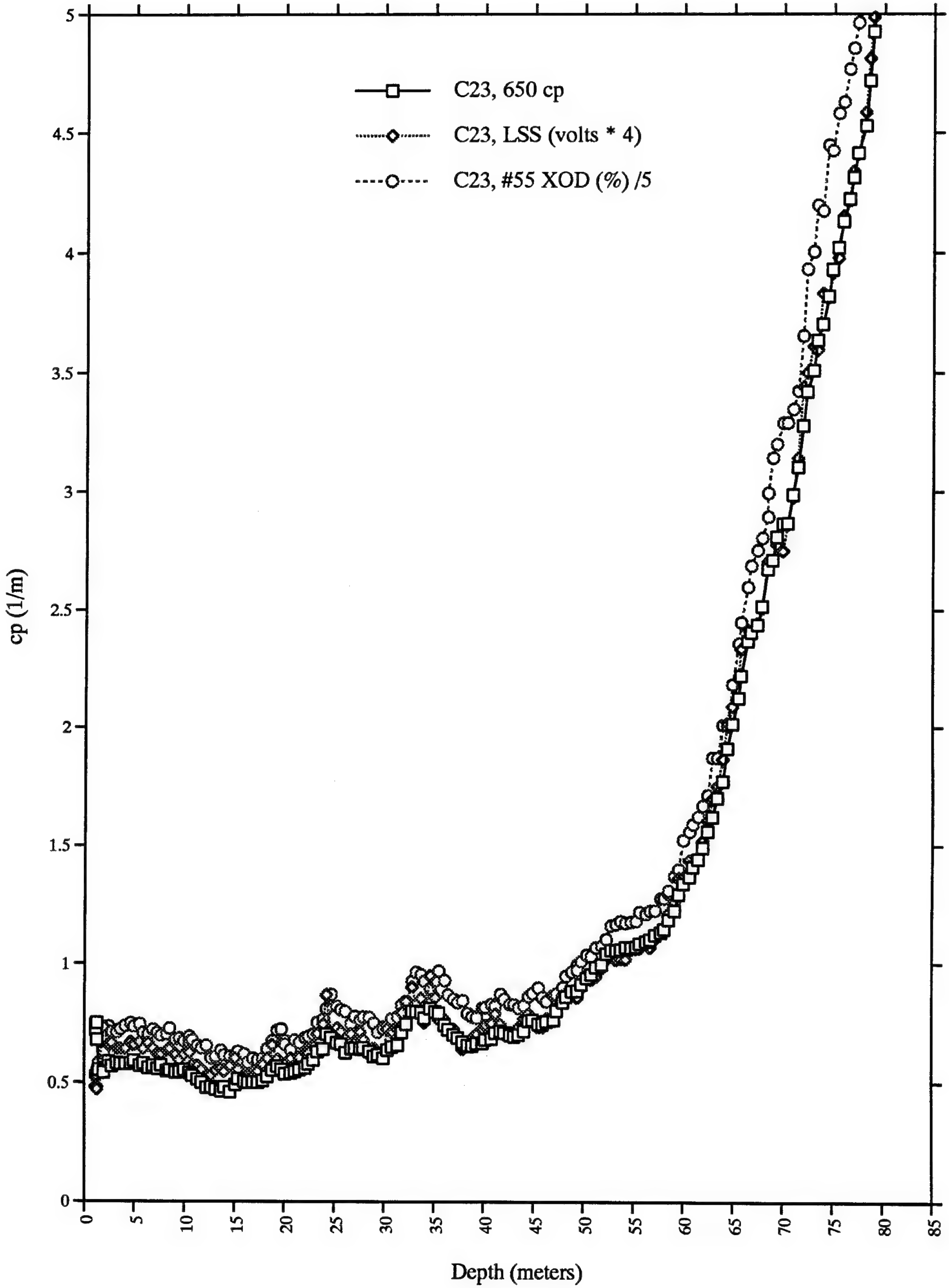
C20, 650 cp
C20, LSS (volts * 4)
C20, #27 XOD (%) / 5
cp (1/m)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
Depth (meters)

Cast 21

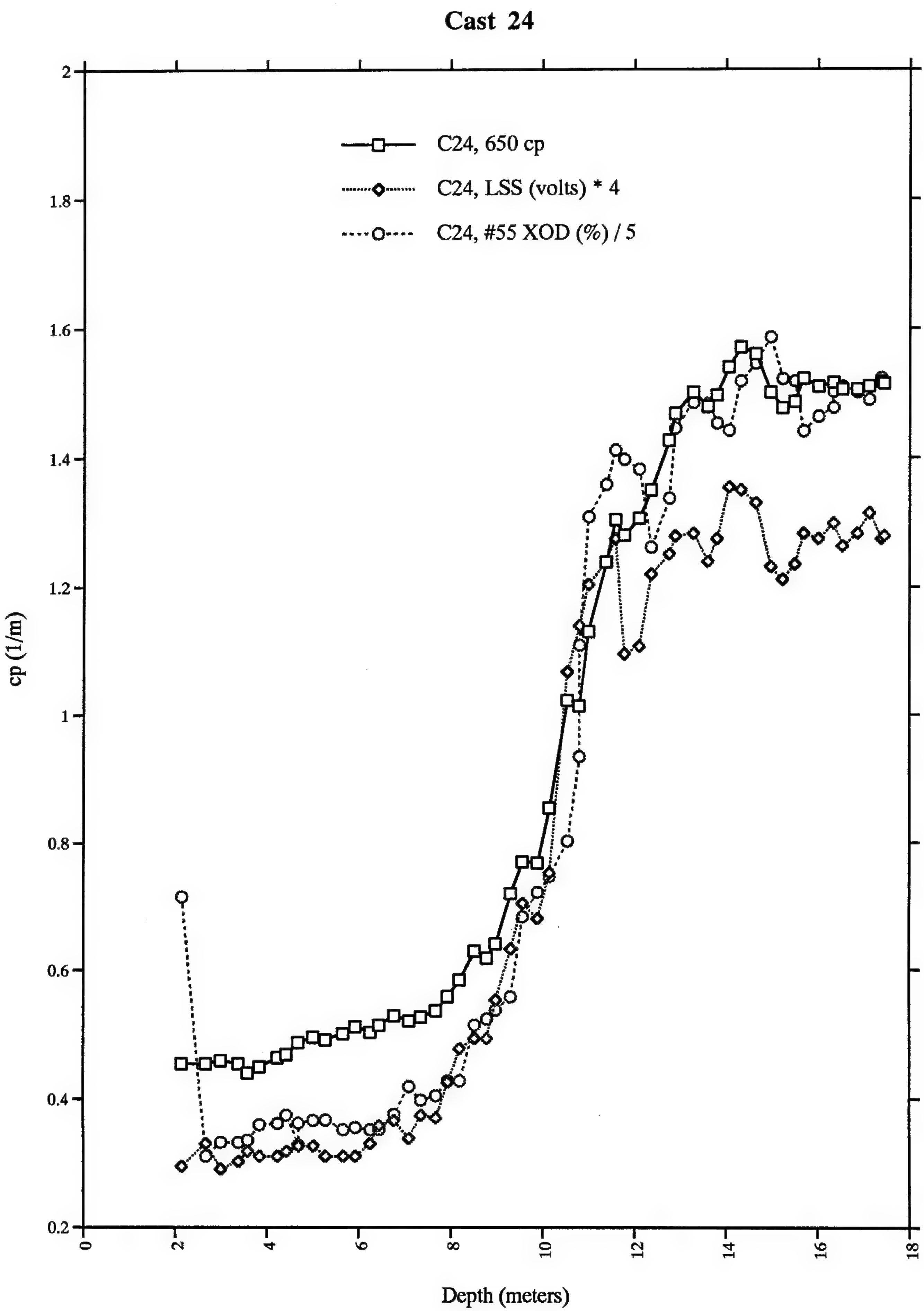


C21, 650nm cp
C21, LSS (volts * 4)
C21, #55 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

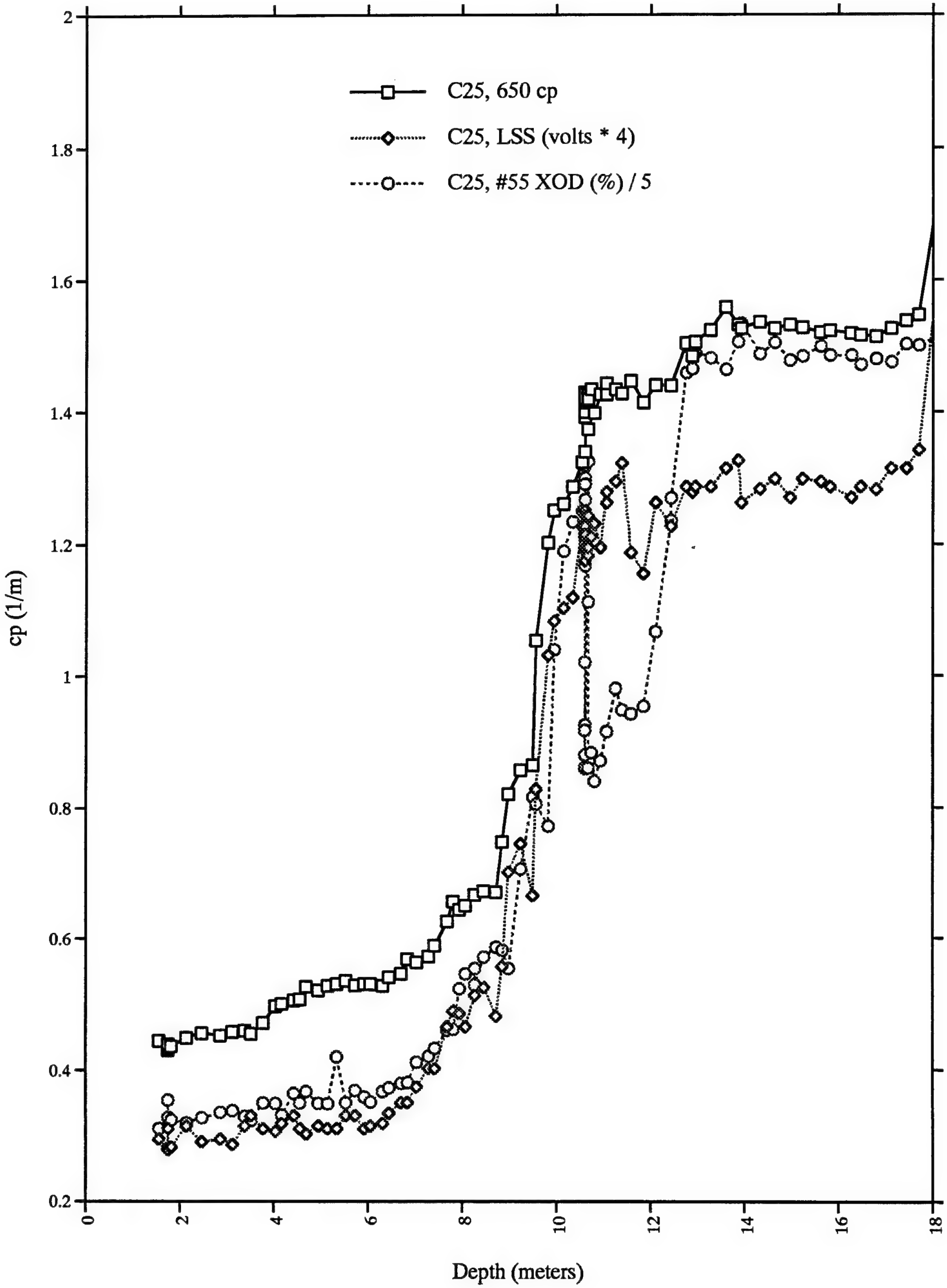
Cast 23



C23, 650 cp
C23, LSS (volts * 4)
C23, #55 XOD (%) /5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85

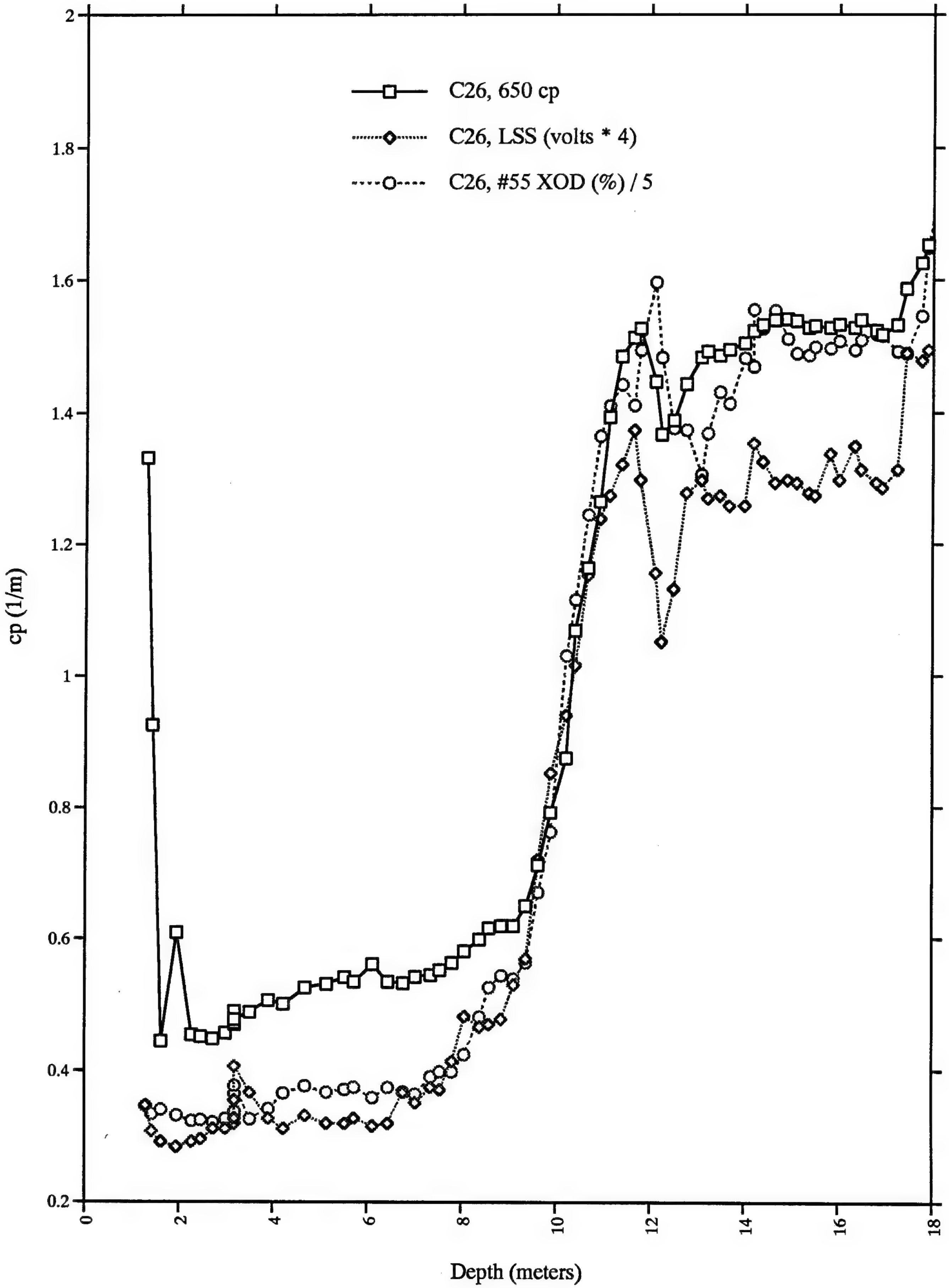

Cast 24
C24, 650 cp
C24, LSS (volts) * 4
C24, #55 XOD (%) / 5
cp (1/m)
Depth (meters)
0
2
4
6
8
10
12
14
16
18
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

Cast 25



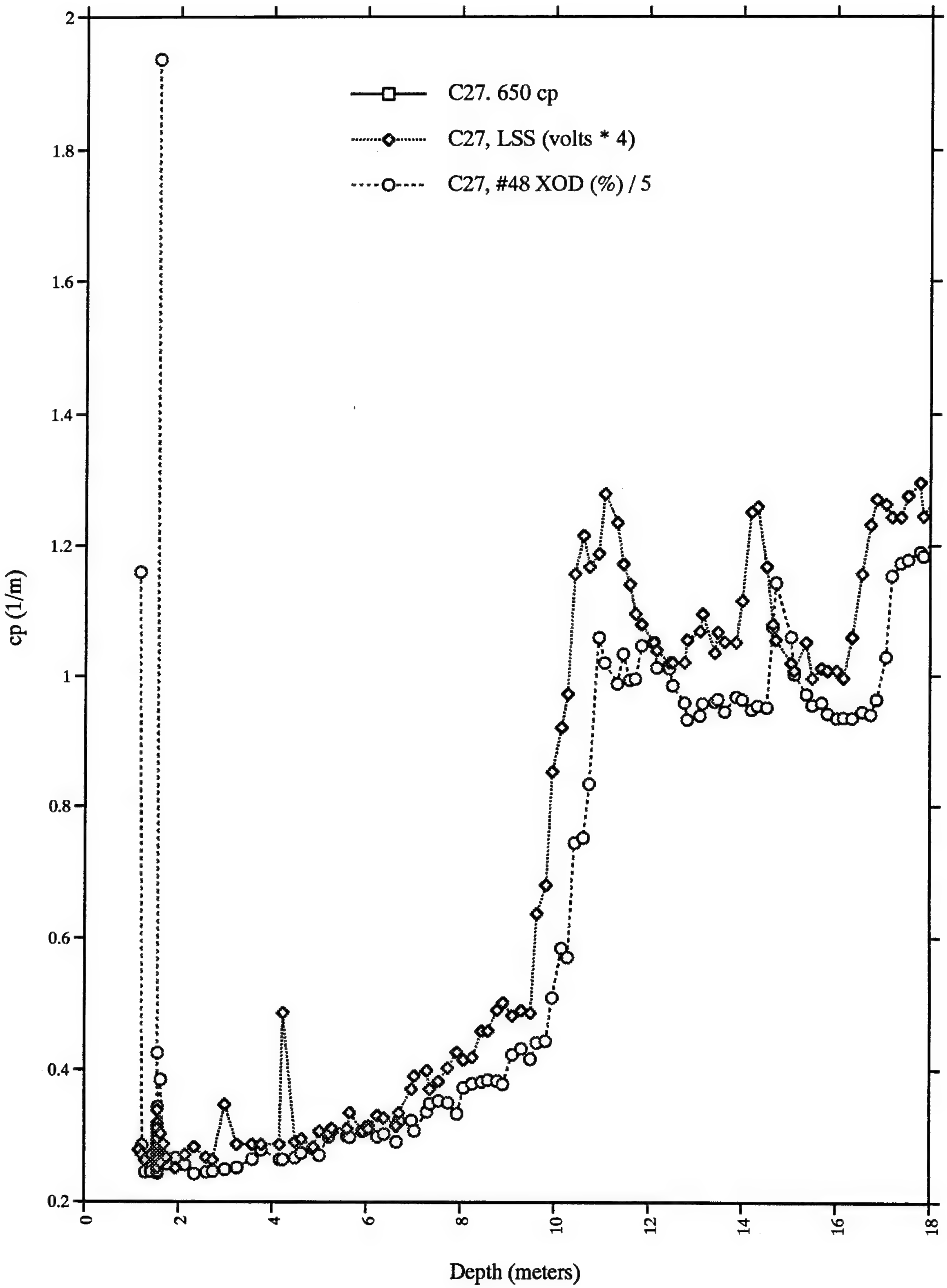
C25, 650 cp
C25, LSS (volts * 4)
C25, #55 XOD (%) / 5
cp (1/m)
Depth (meters)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12
14
16
18

Cast 26



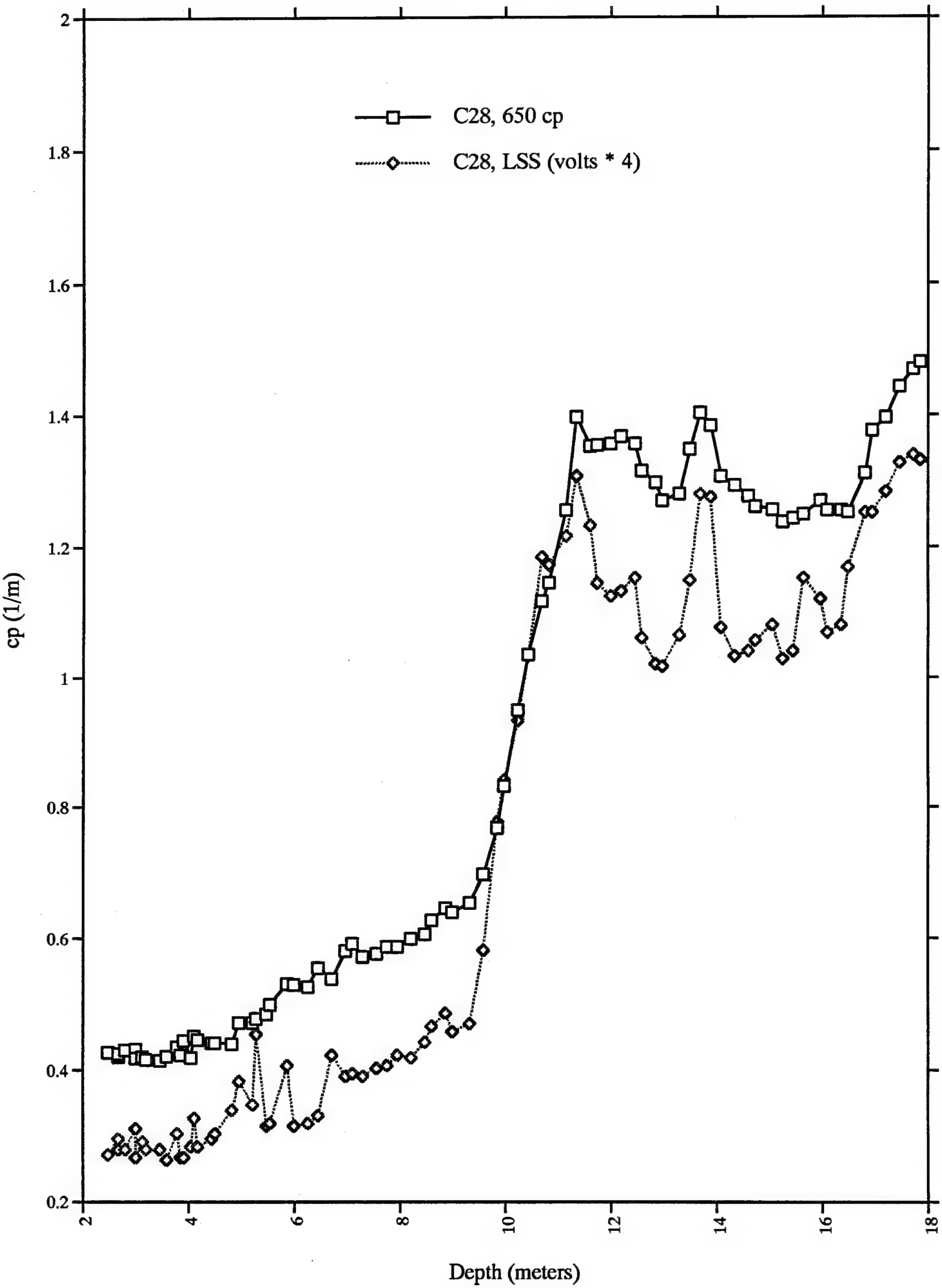
C26, 650 cp
C26, LSS (volts * 4)
C26, #55 XOD (%) / 5
cp (1/m)
Depth (meters)
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
2
4
6
8
10
12
14
16
18

Cast 27



C27. 650 cp
C27, LSS (volts * 4)
C27, #48 XOD (%) / 5
cp (1/m)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12
14
16
18
Depth (meters)

Cast 28

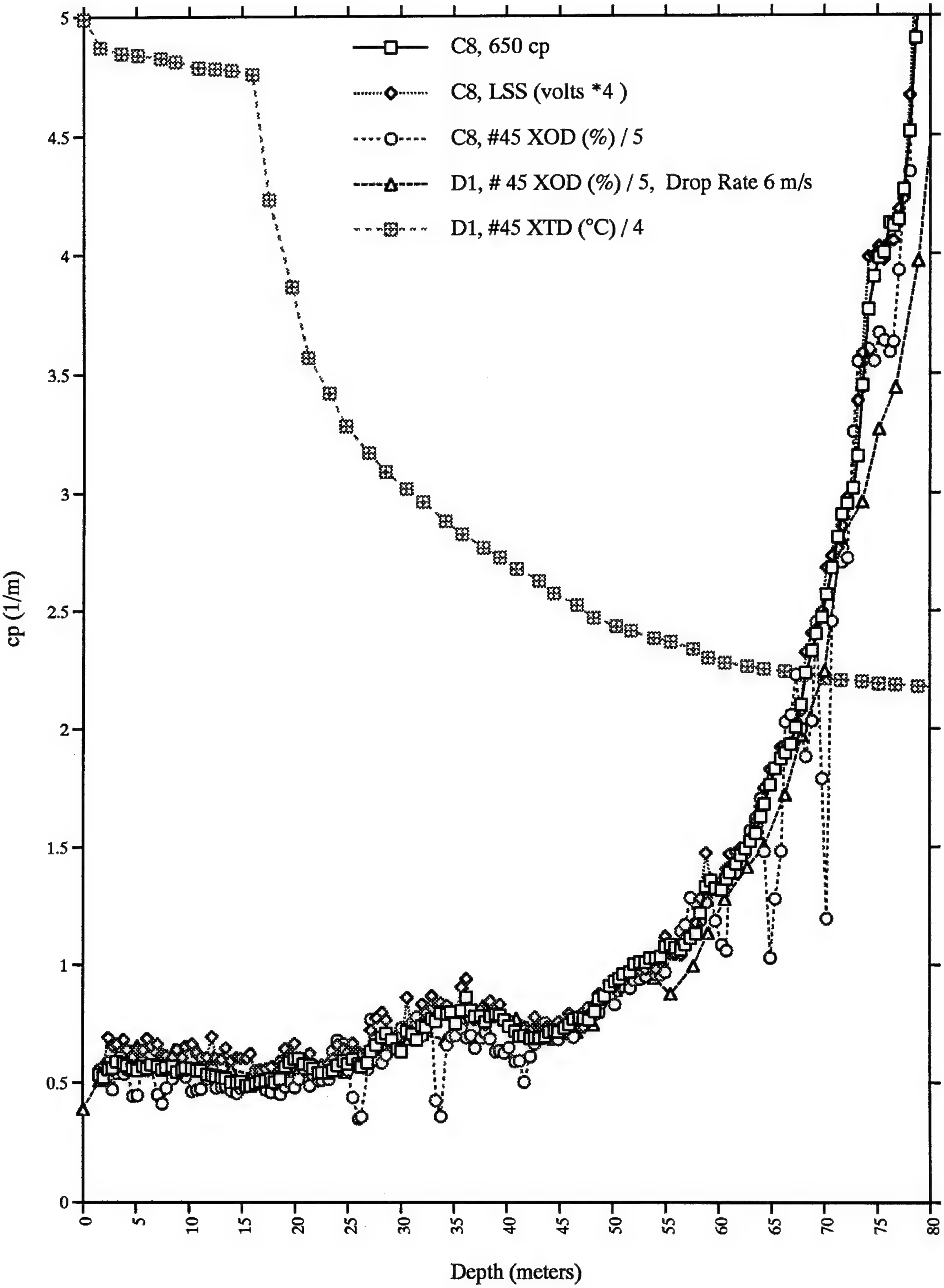


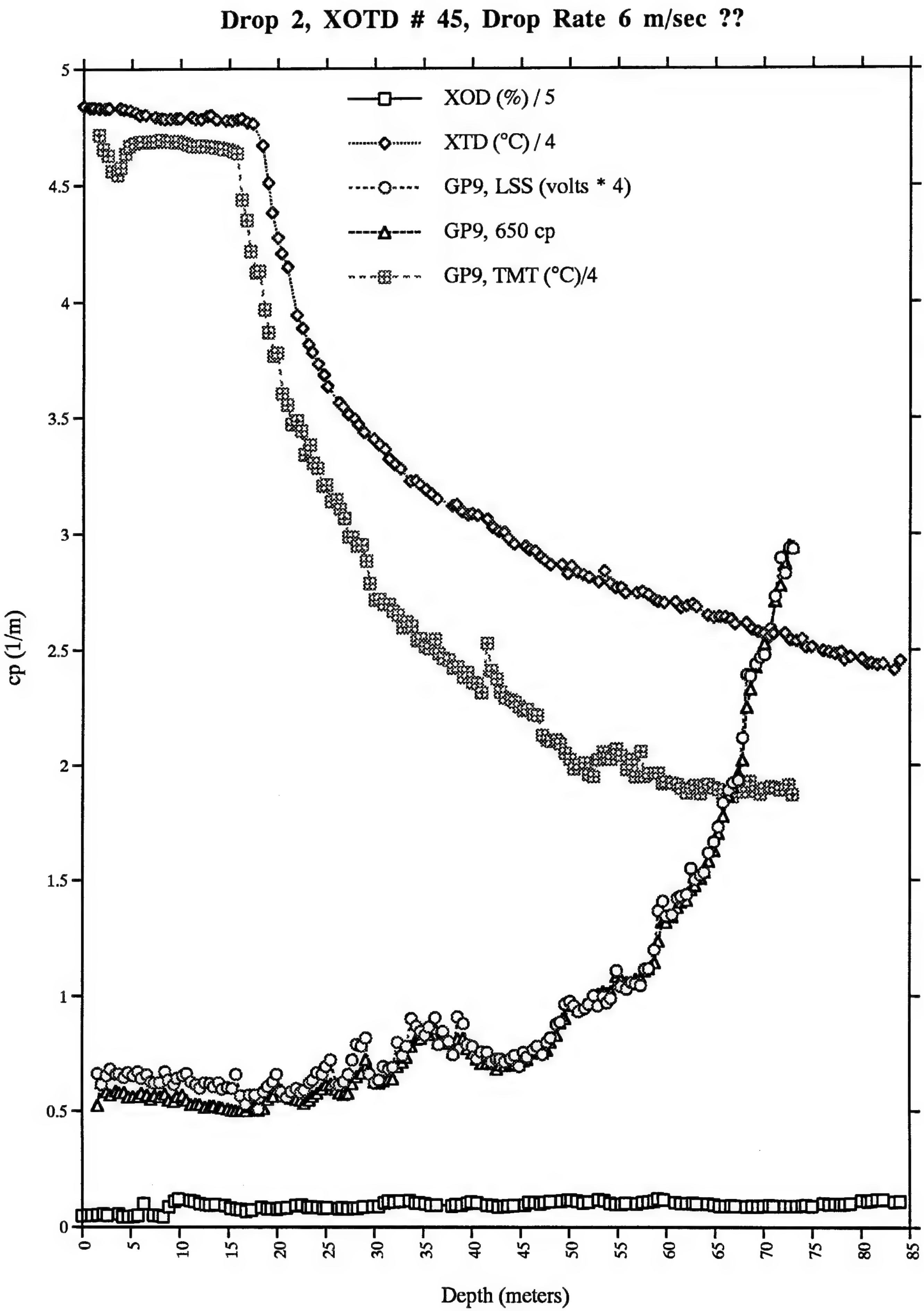
C28, 650 cp
C28, LSS (volts * 4)
cp (1/m)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
2
4
6
8
10
12
14
16
18
Depth (meters)

Field Test Data

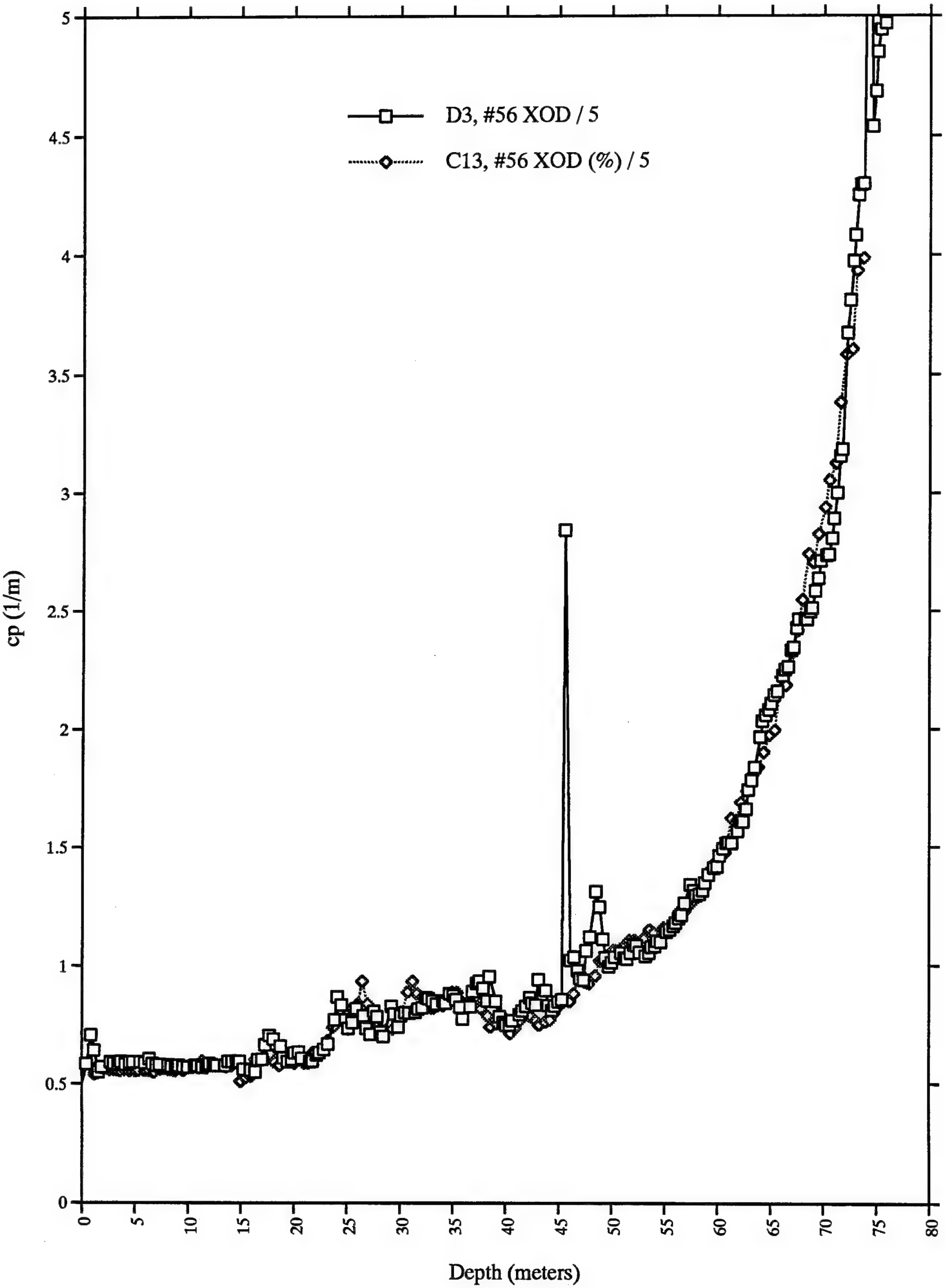
Drops 1 through 24

Drop 1

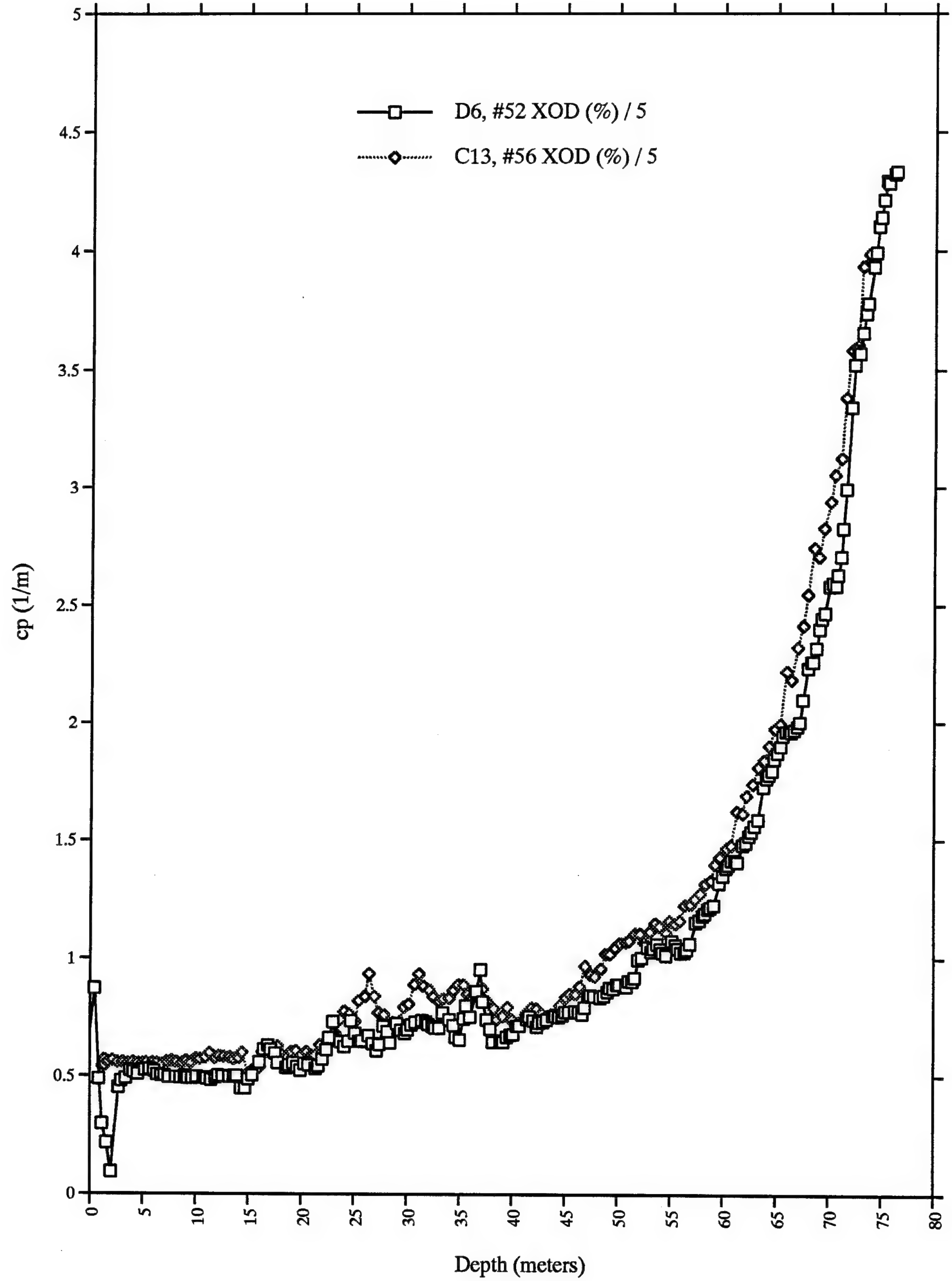

C8, 650 cp
C8, LSS (volts *4)
C8, #45 XOD (%) / 5
D1, # 45 XOD (%) / 5, Drop Rate 6 m/s
D1, #45 XTD (°C) / 4
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80


Drop 2, XOTD # 45, Drop Rate 6 m/sec ??
XOD (%) / 5
XTD (°C) / 4
GP9, LSS (volts * 4)
GP9, 650 cp
GP9, TMT (°C)/4
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85

Drop 3

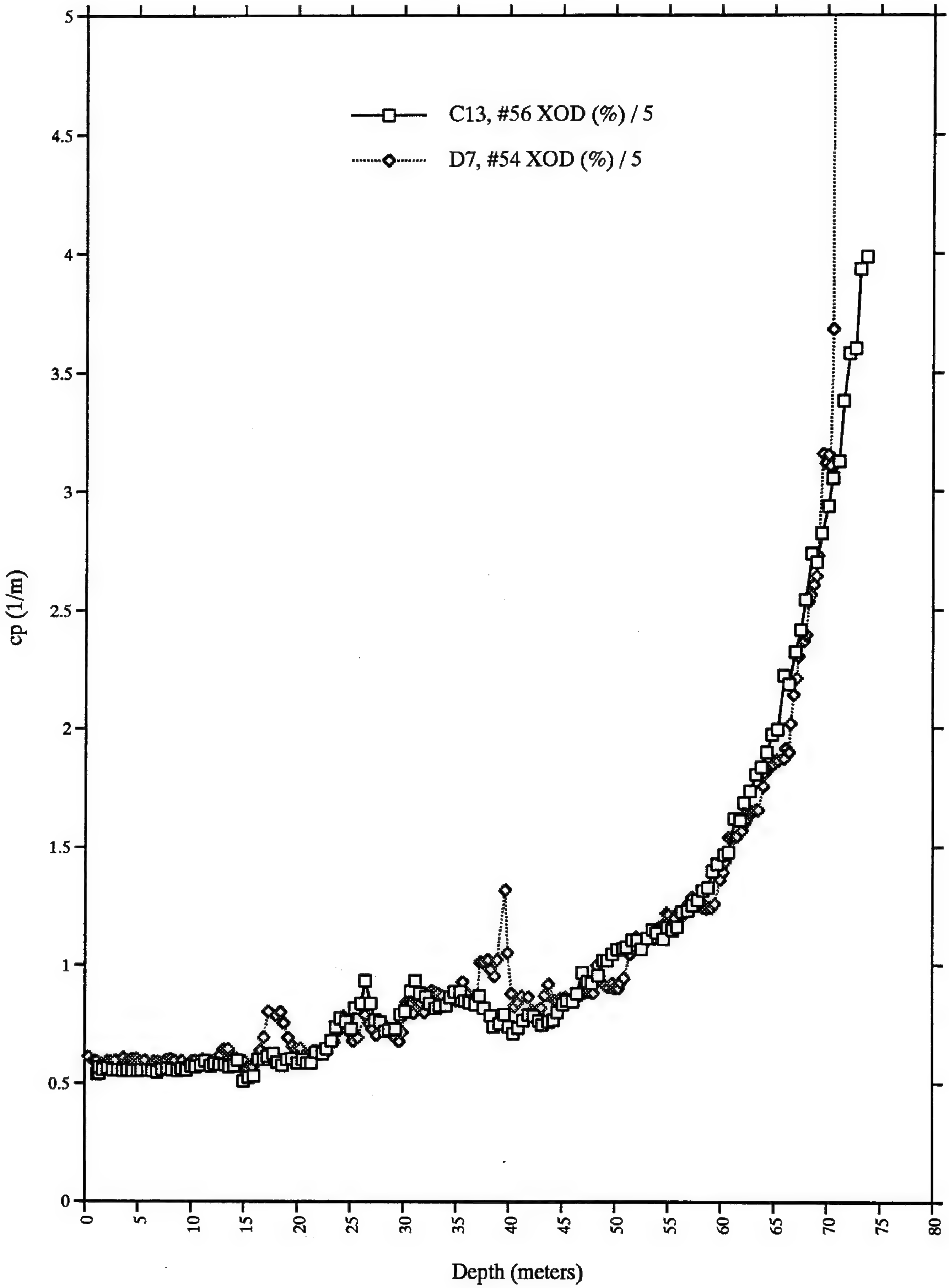

D3, #56 XOD / 5
C13, #56 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

Drop 6

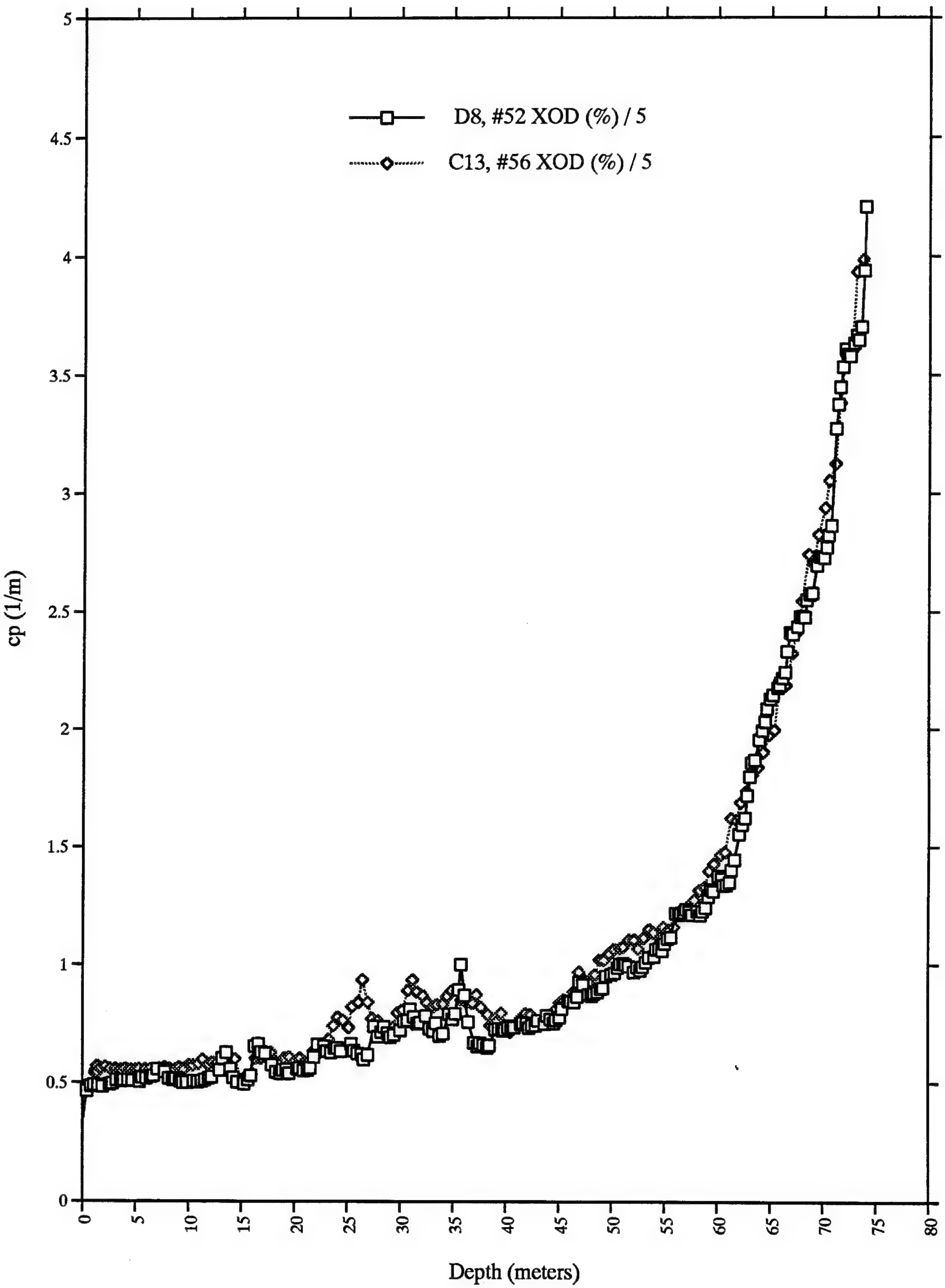


D6, #52 XOD (%) / 5
C13, #56 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

Drop 7

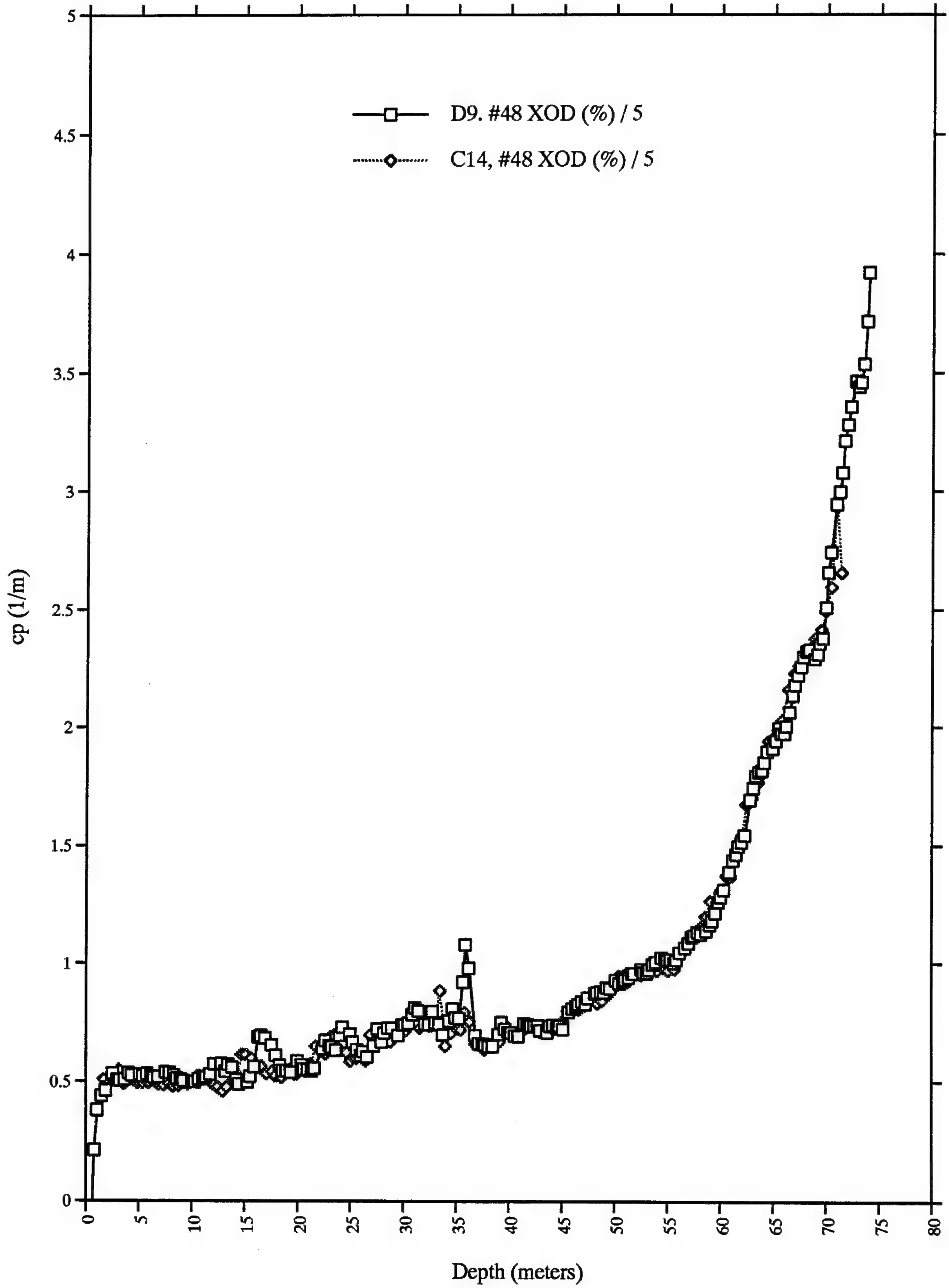

C13, #56 XOD (%) / 5
D7, #54 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

Drop 8

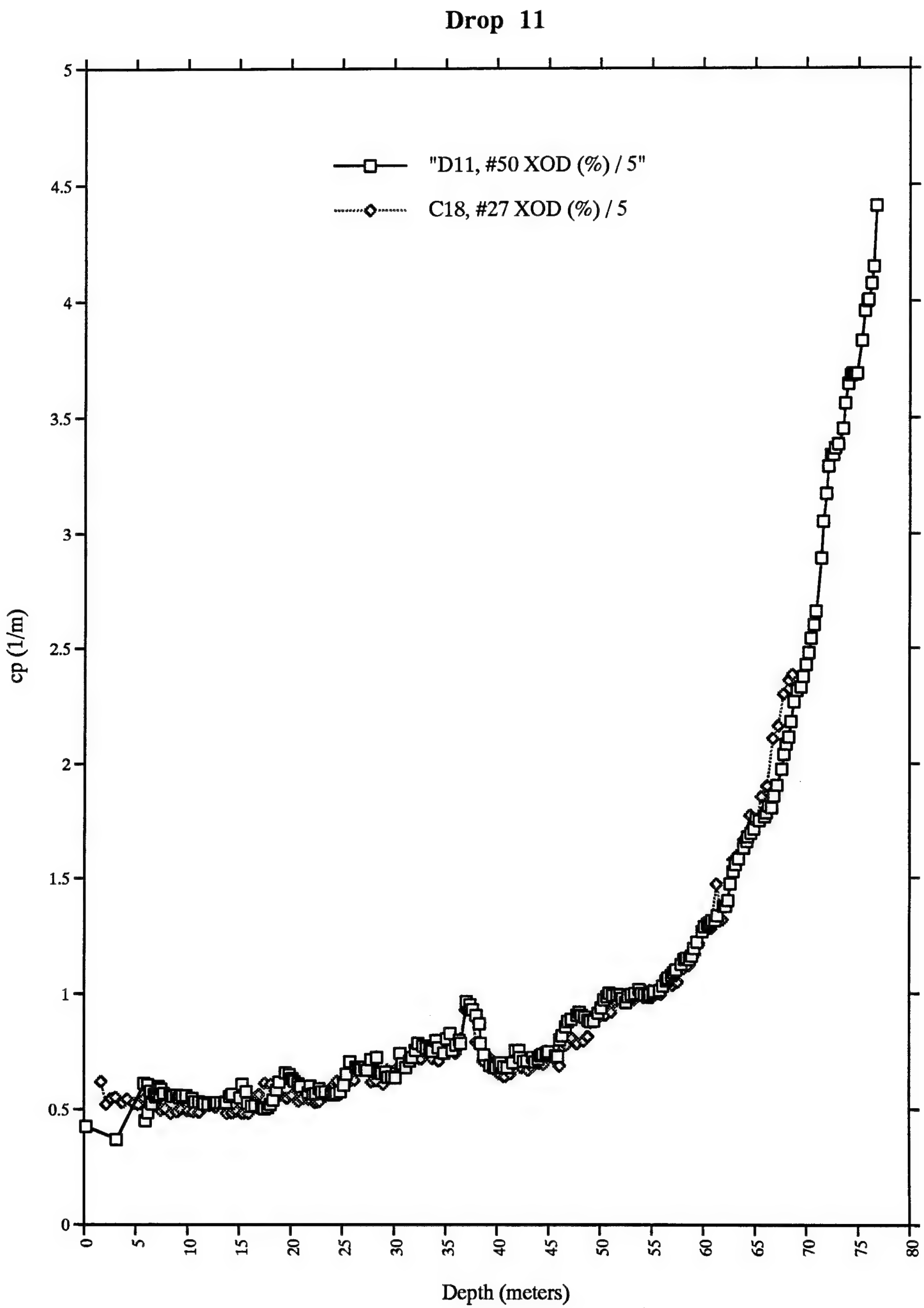


D8, #52 XOD (%) / 5
C13, #56 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

Drop 9

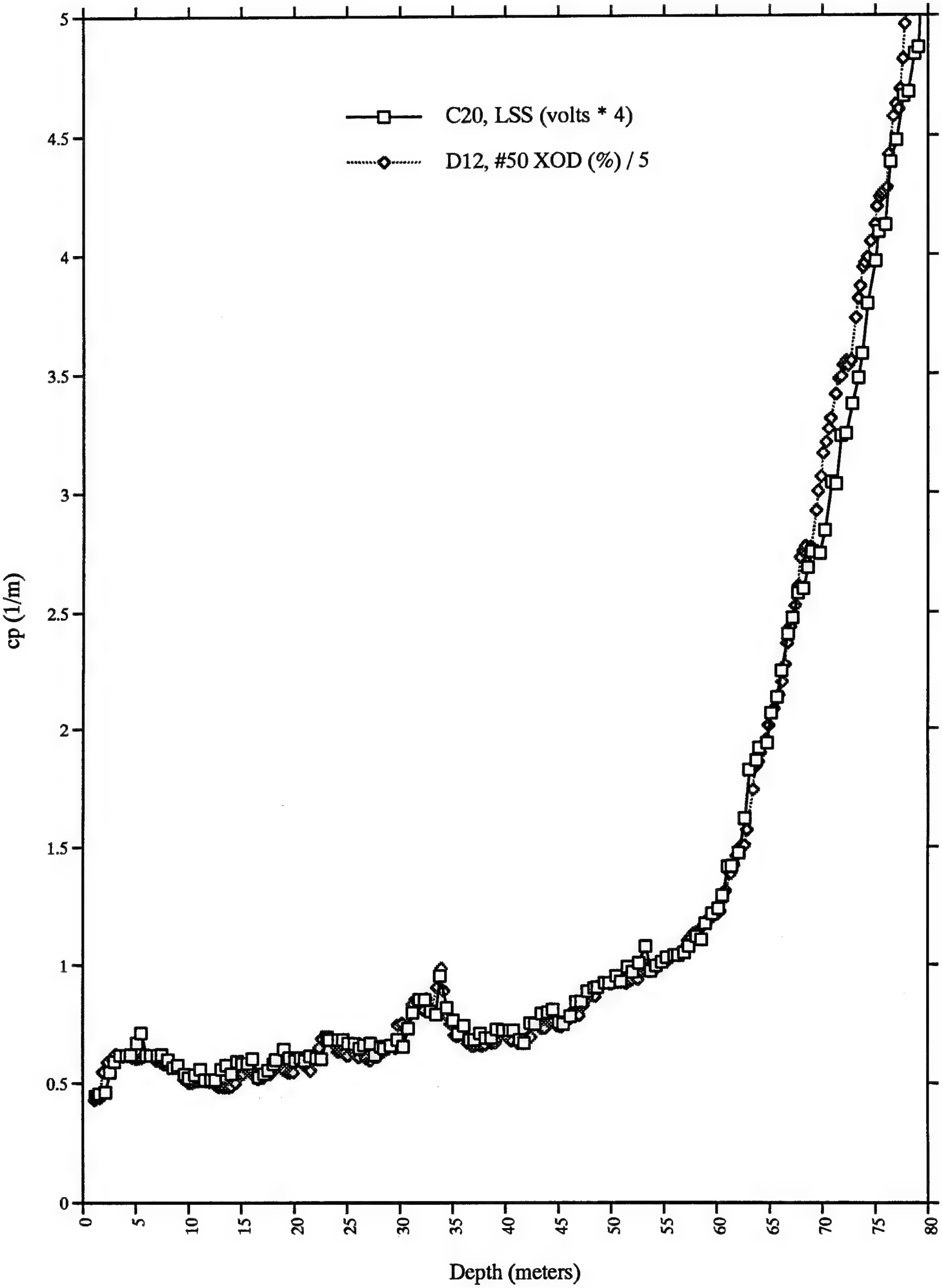


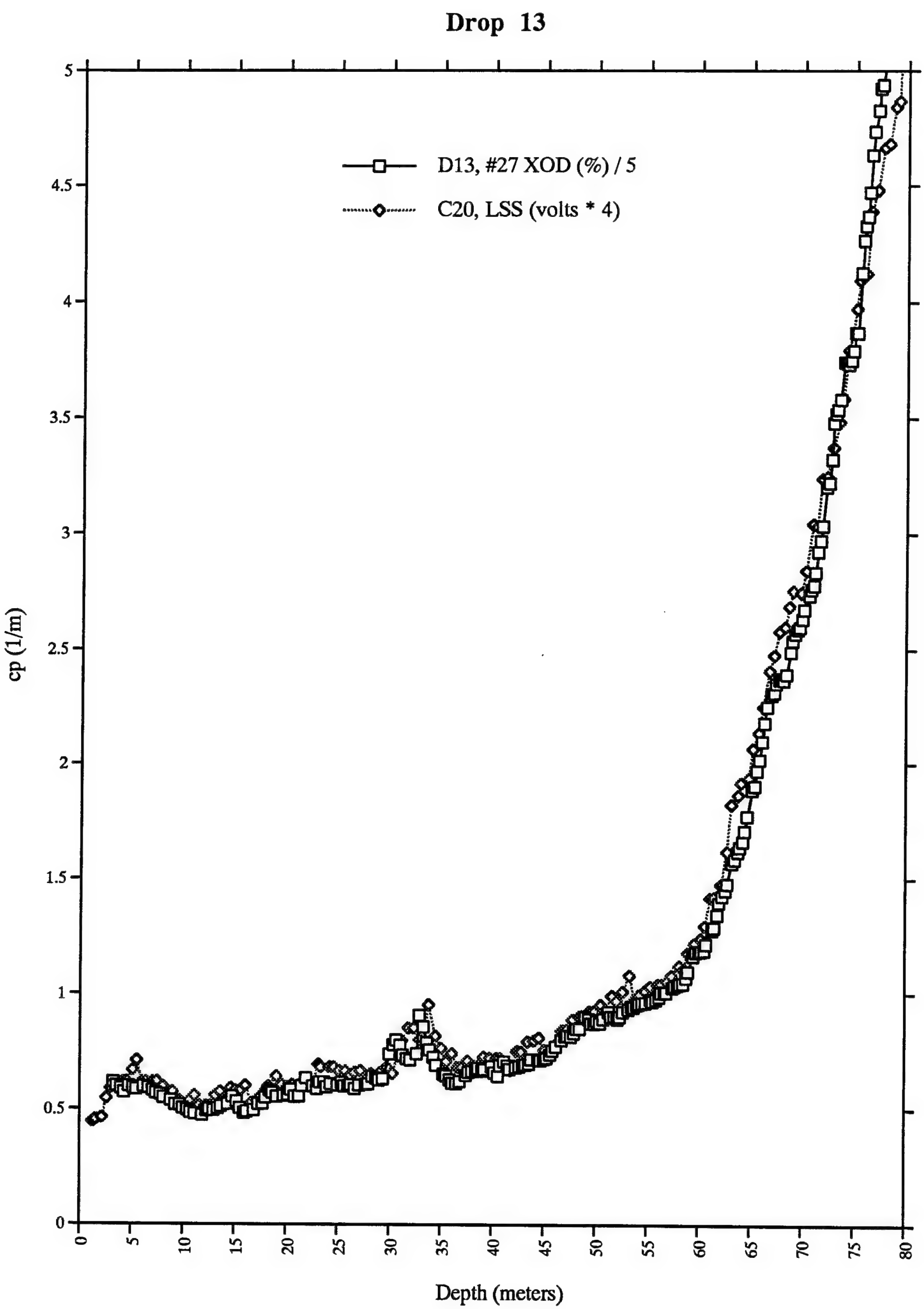
D9. #48 XOD (%) / 5
C14, #48 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80



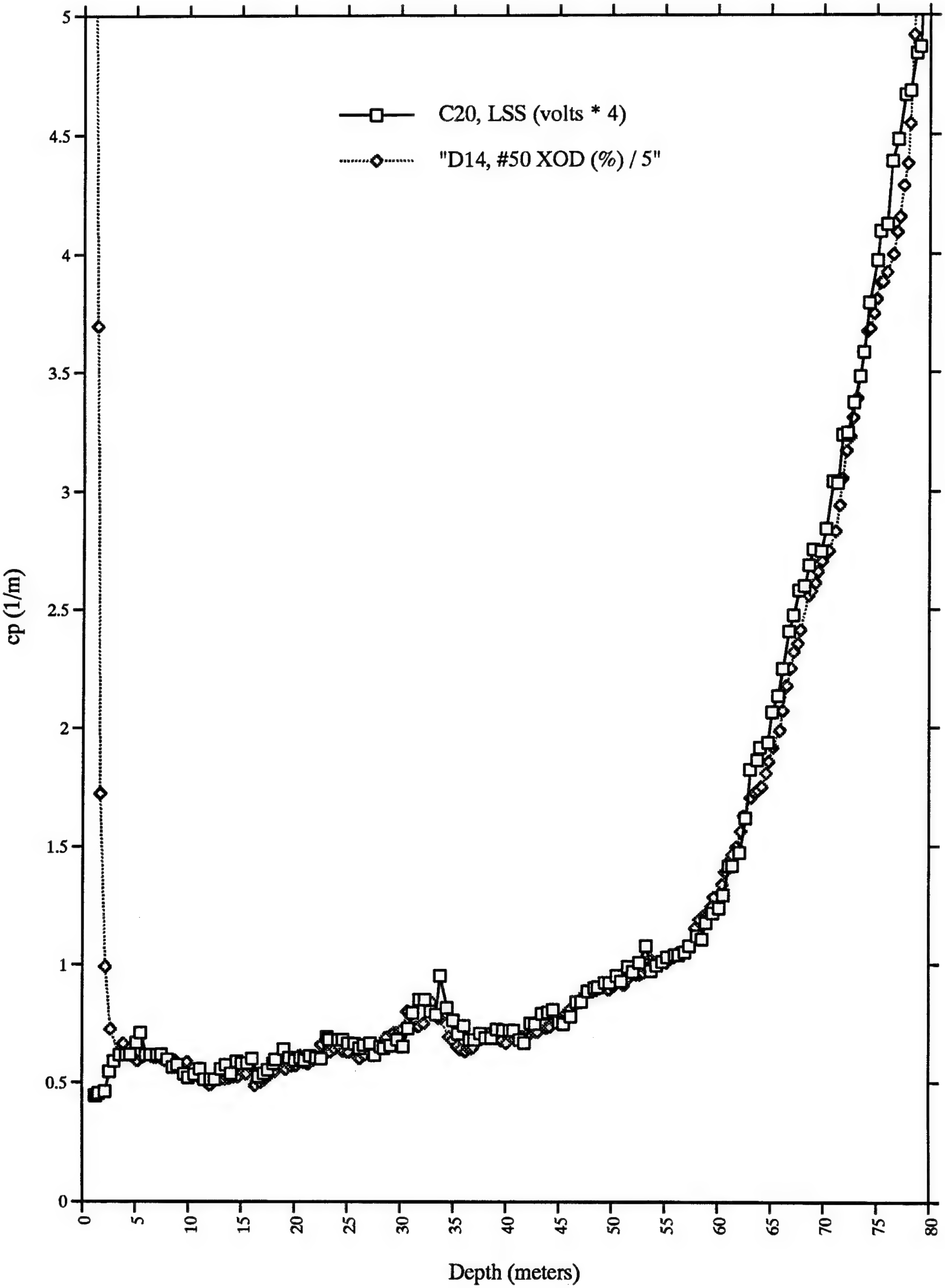
Drop 11
"D11, #50 XOD (%) / 5"
C18, #27 XOD (%) / 5
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

Cast 20 & Drop 12



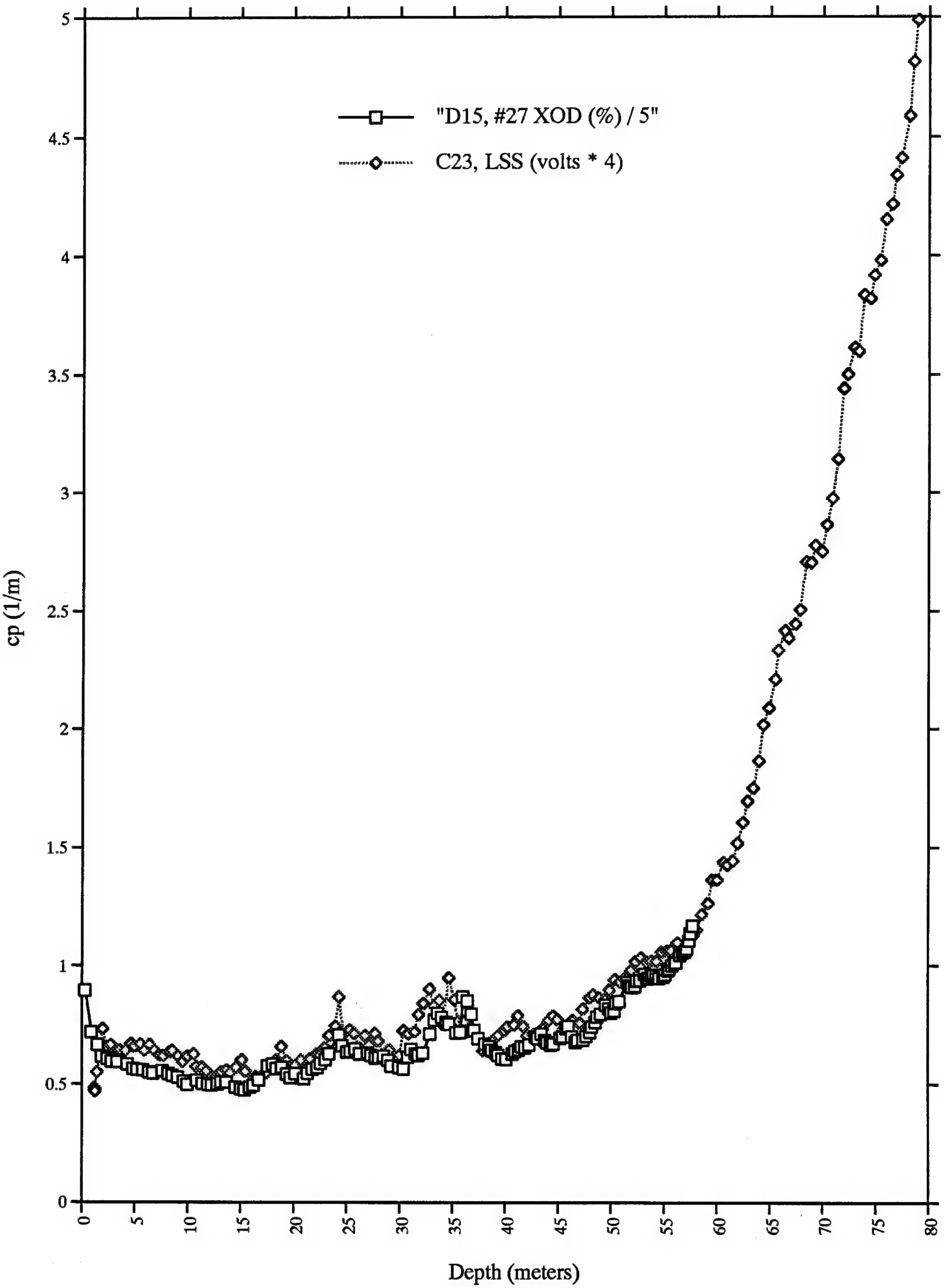

Drop 13
D13, #27 XOD (%) / 5
C20, LSS (volts * 4)
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

Drop 14

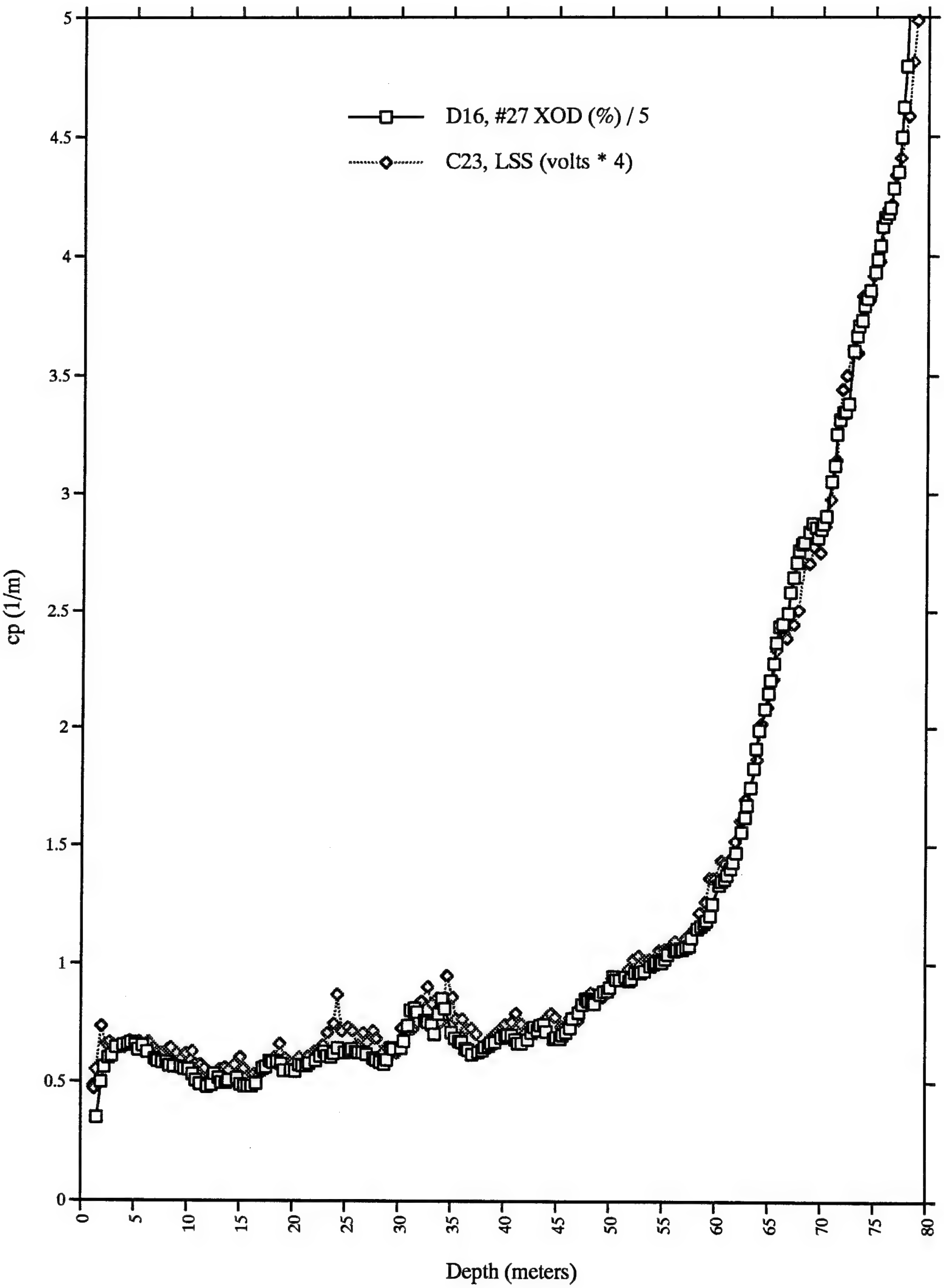


C20, LSS (volts * 4)
"D14, #50 XOD (%) / 5"
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

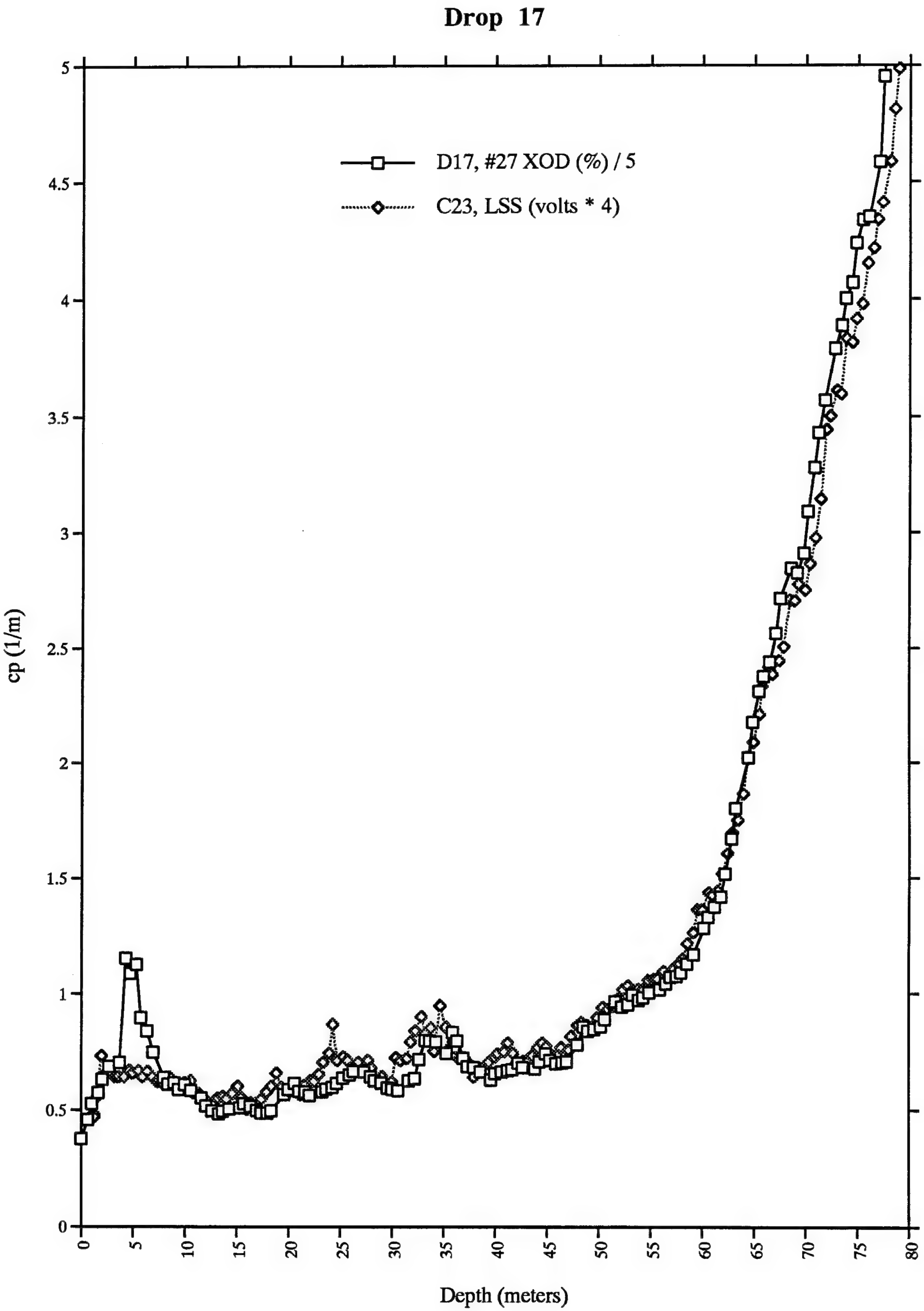
Drop 15


"D15, #27 XOD (%) / 5"
C23, LSS (volts * 4)
cp (1/m)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
Depth (meters)

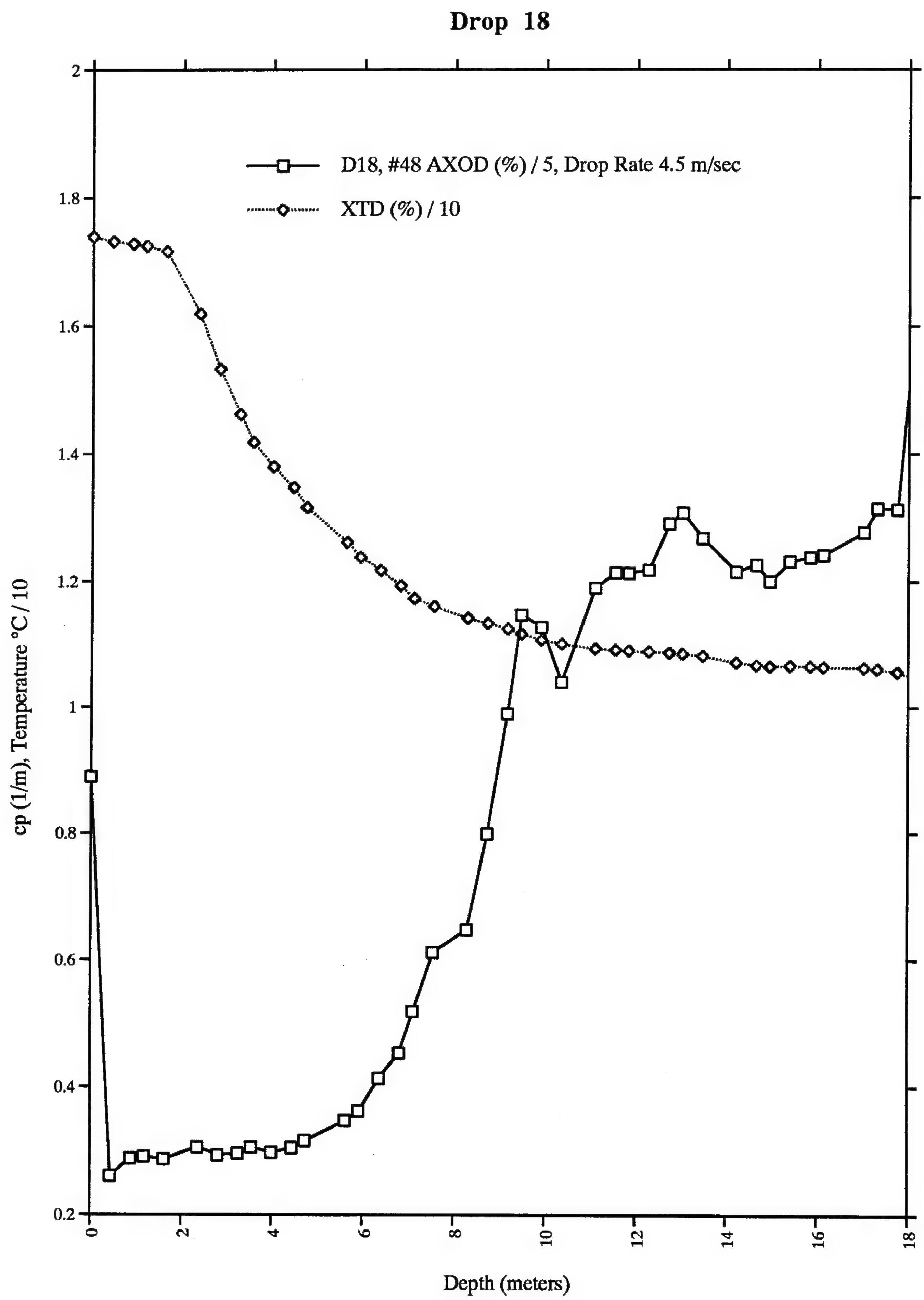
Drop 16



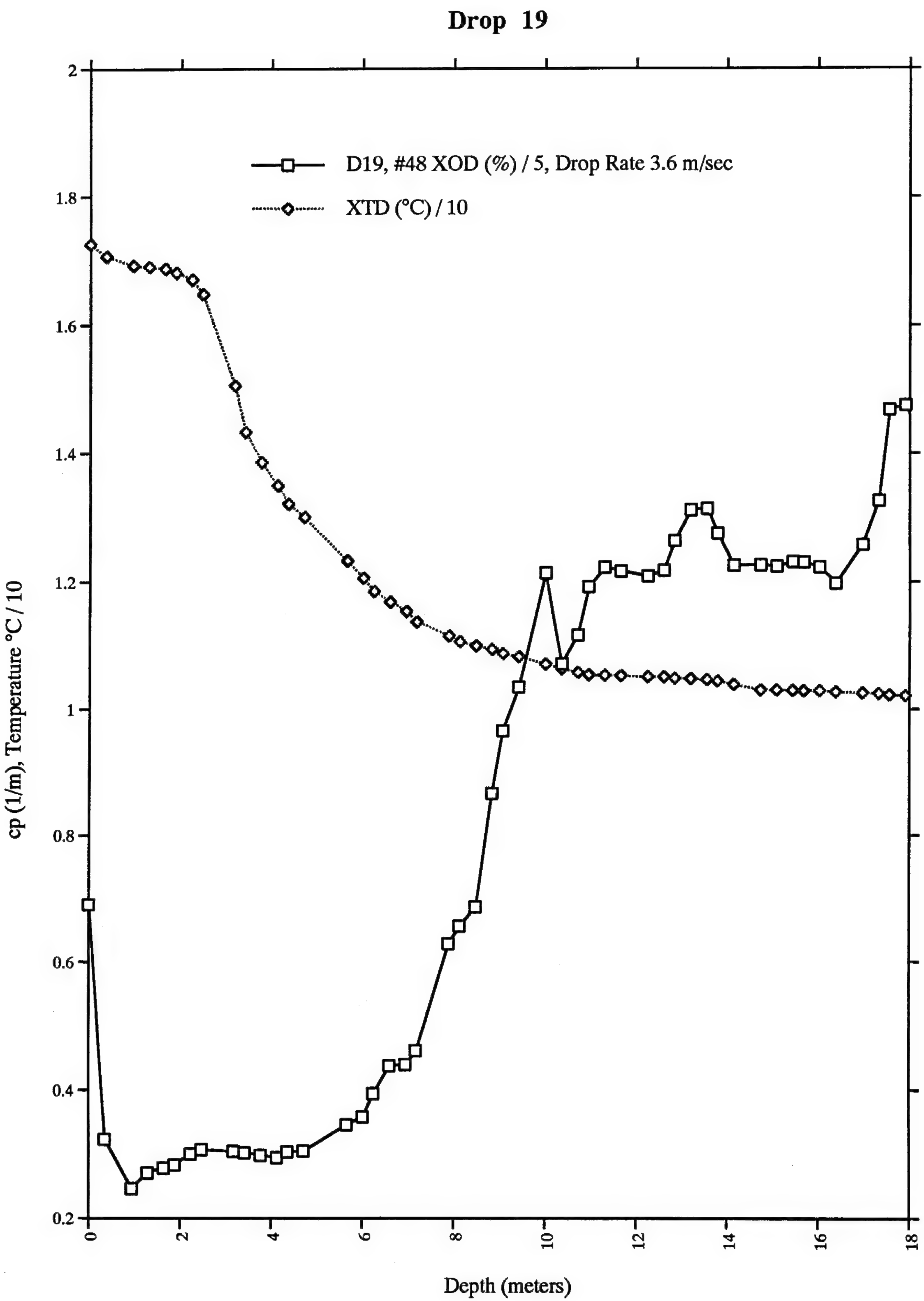
D16, #27 XOD (%) / 5
C23, LSS (volts * 4)
cp (1/m)
Depth (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80



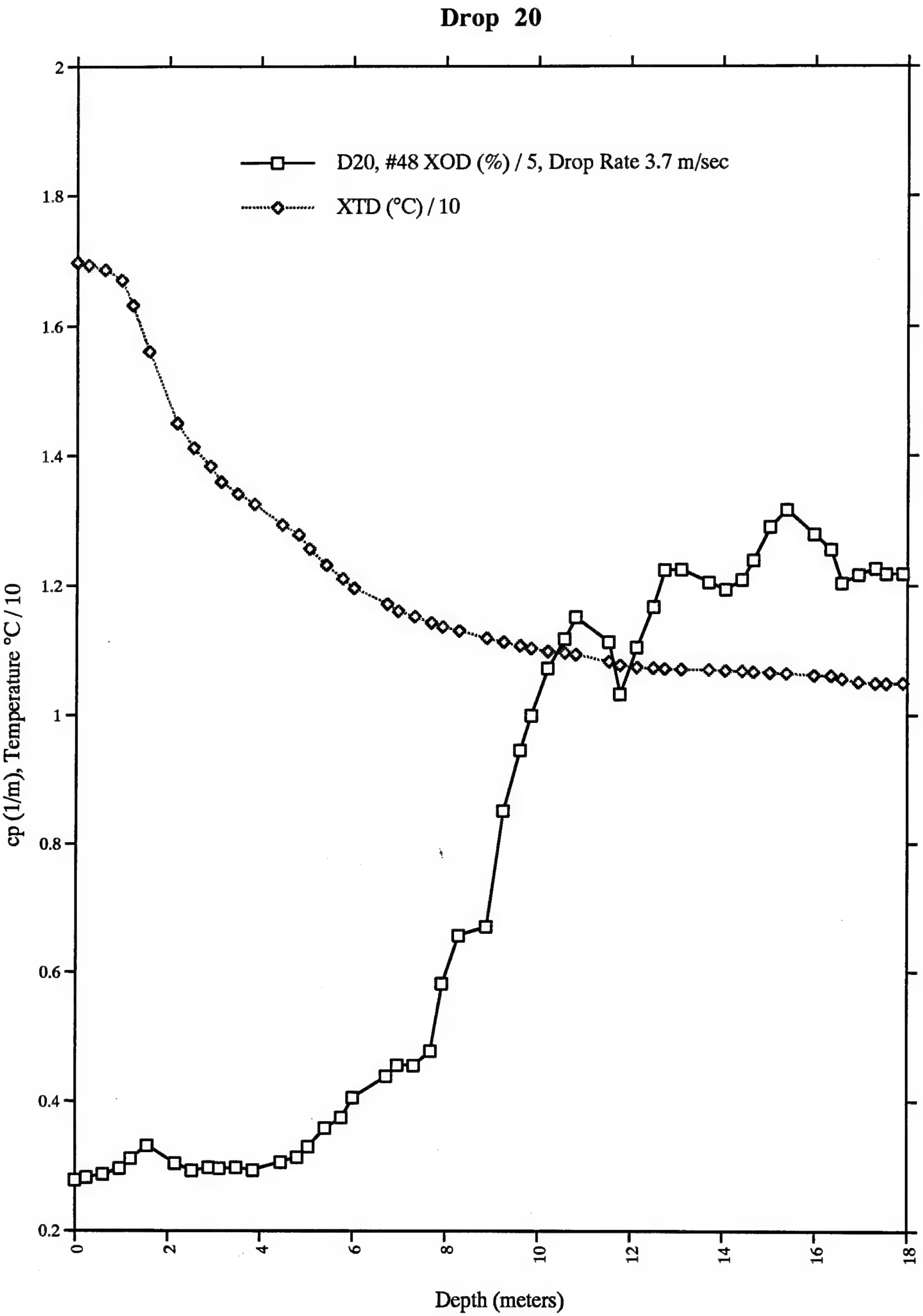
Drop 17
D17, #27 XOD (%) / 5
C23, LSS (volts * 4)
cp (1/m)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
Depth (meters)



Drop 18
D18, #48 AXOD (%) / 5, Drop Rate 4.5 m/sec
XTD (%) / 10
cp (1/m), Temperature °C / 10
Depth (meters)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12
14
16
18

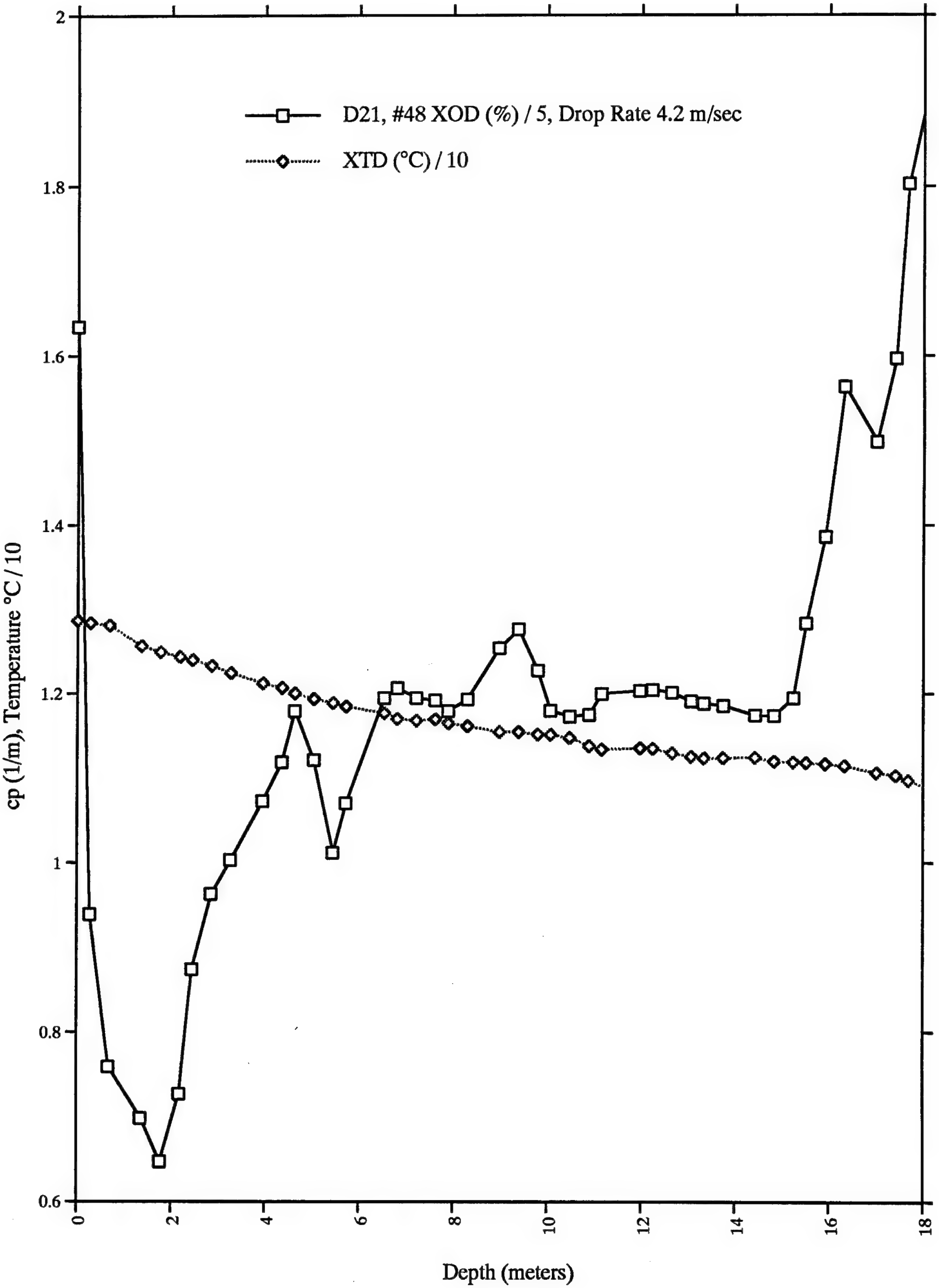


Drop 19
D19, #48 XOD (%) / 5, Drop Rate 3.6 m/sec
XTD (°C) / 10
cp (1/m), Temperature °C / 10
Depth (meters)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12
14
16
18

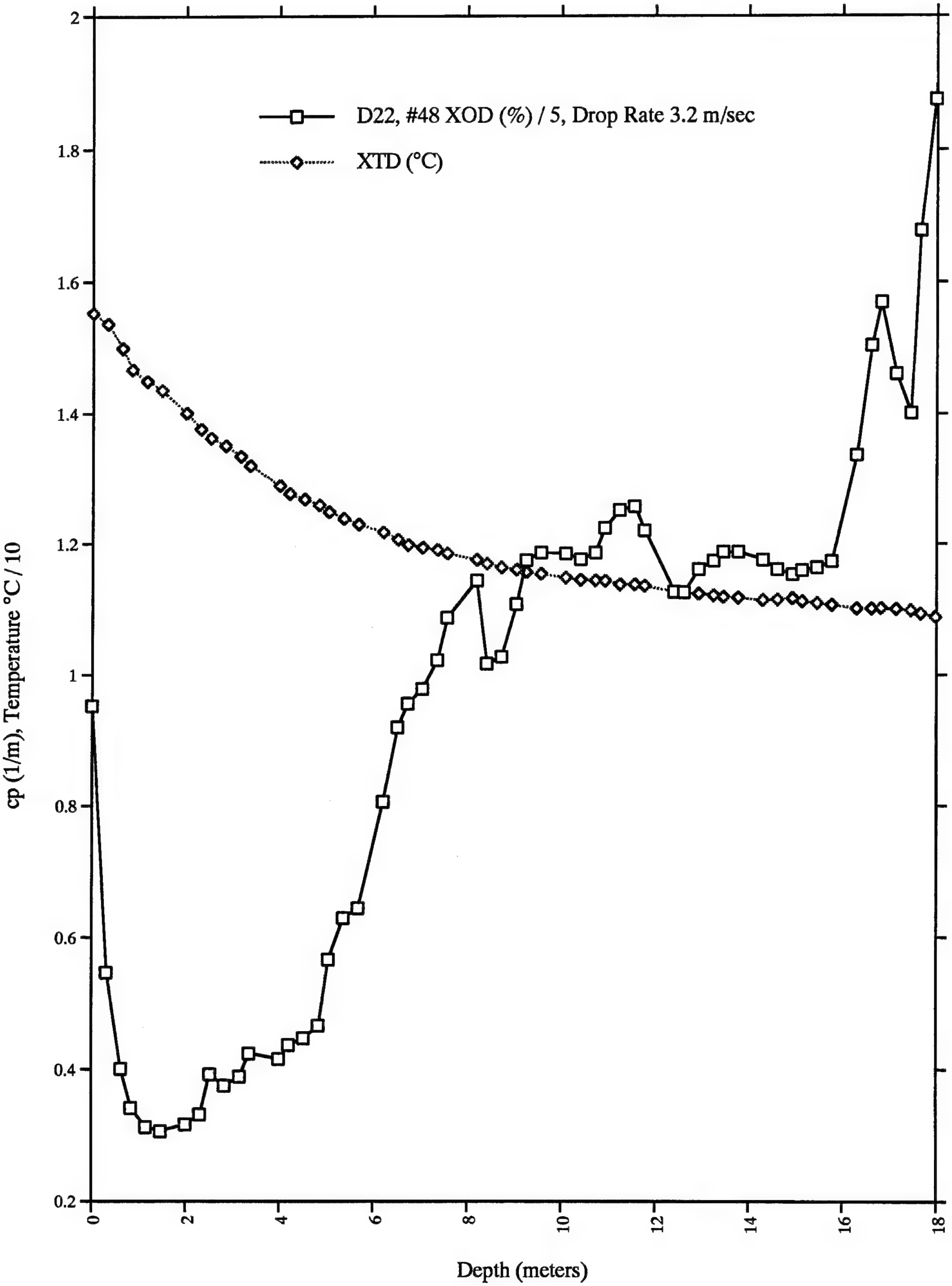


Drop 20
D20, #48 XOD (%) / 5, Drop Rate 3.7 m/sec
XTD (°C) / 10
cp (1/m), Temperature °C / 10
Depth (meters)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12
14
16
18

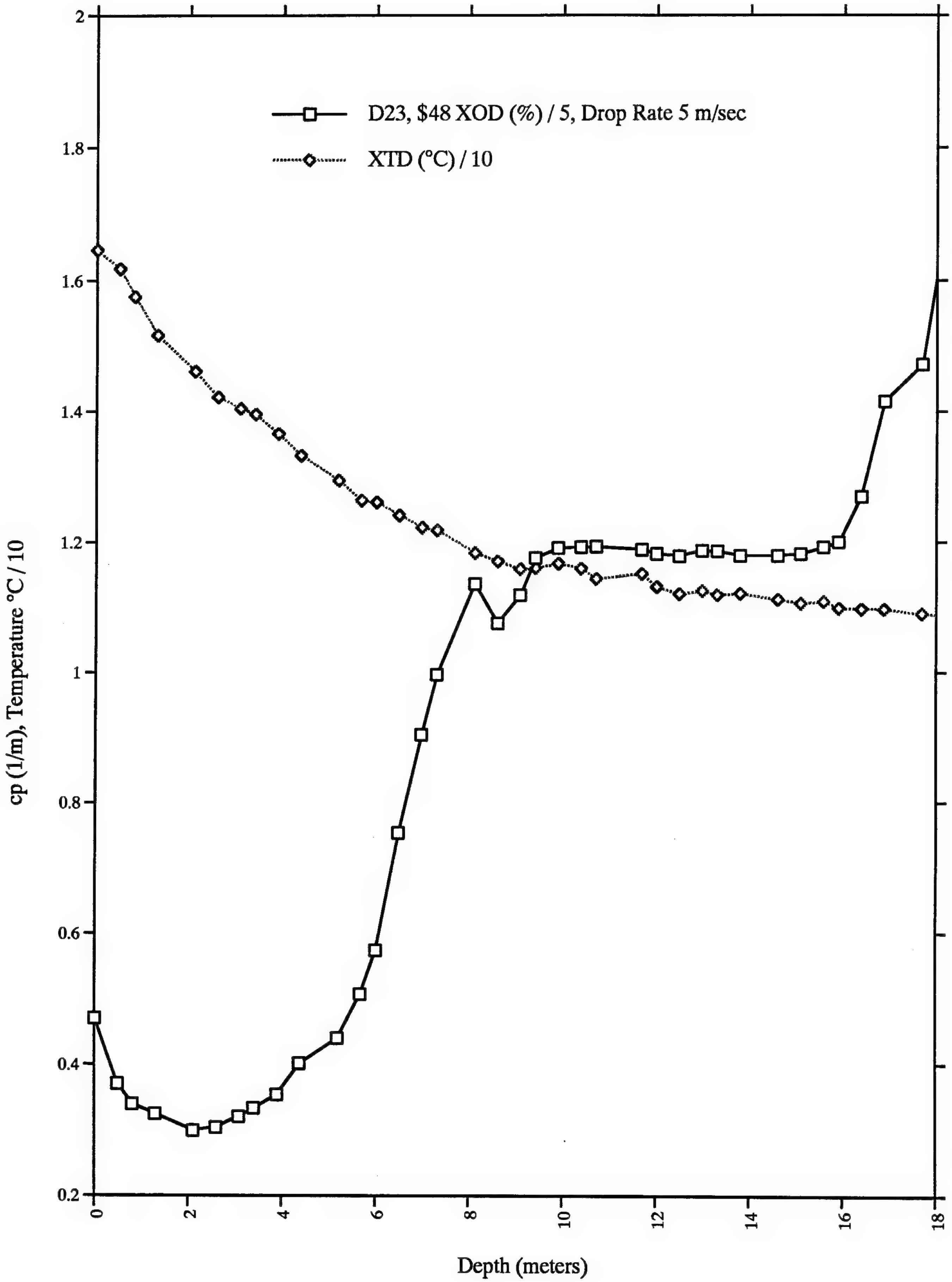
Drop 21


D21, #48 XOD (%) / 5, Drop Rate 4.2 m/sec
XTD (°C) / 10
cp (1/m), Temperature °C / 10
Depth (meters)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0
2
4
6
8
10
12
14
16
18

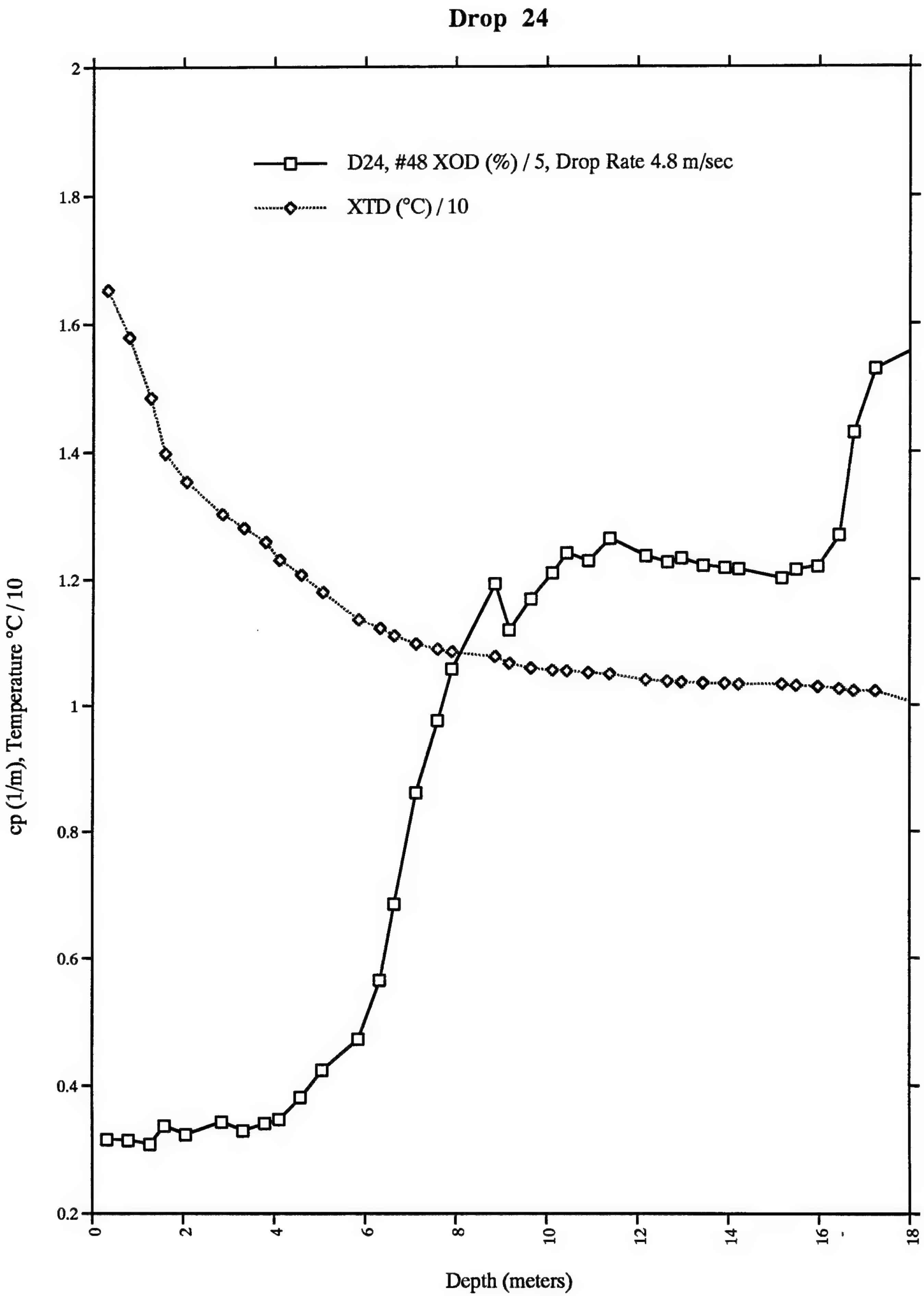
Drop 22


D22, #48 XOD (%) / 5, Drop Rate 3.2 m/sec
XTD (°C)
cp (1/m), Temperature °C / 10
Depth (meters)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12
14
16
18

Drop 23



D23, $48 XOD (%) / 5, Drop Rate 5 m/sec
XTD (°C) / 10
cp (1/m), Temperature °C / 10
Depth (meters)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12
14
16
18


Drop 24
D24, #48 XOD (%) / 5, Drop Rate 4.8 m/sec
XTD (°C) / 10
cp (1/m), Temperature °C / 10
Depth (meters)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12
14
16
18

Appendix B

Field Test Data Analysis

A&XOTD Problems:

The AXOTD start time is quite unreliable as the data shows in figure 1. The main reason for this is that the Sparton computer interface software did not synchronize start of data with the detection of a valid data frame. Valid data was detected by the first edge seen at the output of the line receiver which obviously does not work nor should it be expected to work. This is not the way to handle telemetry data and demonstrates a lack of knowledge on the part of both the engineer and computer programmer at Sparton. Sparton is advised to implement the algorithm used by Sea Tech to detect data start. The computer program using this algorithm was supplied to Sparton at the start of this program over two years ago.

Figure 1 Raw Data AXO48, 6 Drops

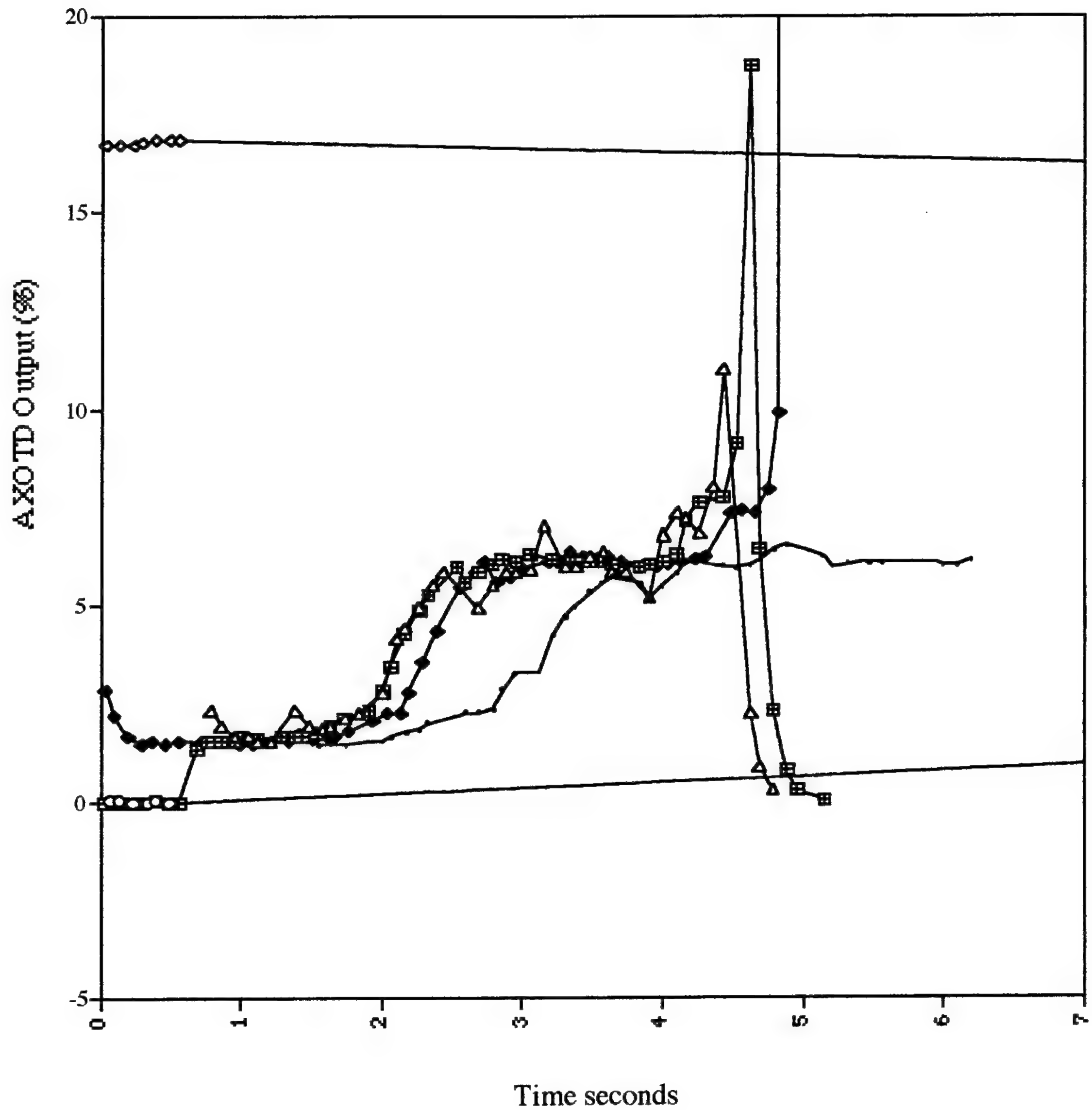


Figure 2 shows the variation in drop time to the bottom after the data was corrected for false starts and is almost unbelievable. Can drop rate vary this much or is the problem with the sensor turn on time, perhaps the sea water switch is not functioning properly in this probe? In any event this demonstrates the problems encountered when the data was reduced. Even with the drop rate problem it is clear that the optical sensor is functioning properly showing two distinct layers of suspended particulates in the water column.

Figure 2 AXOTD Serial Number 48, All Drops

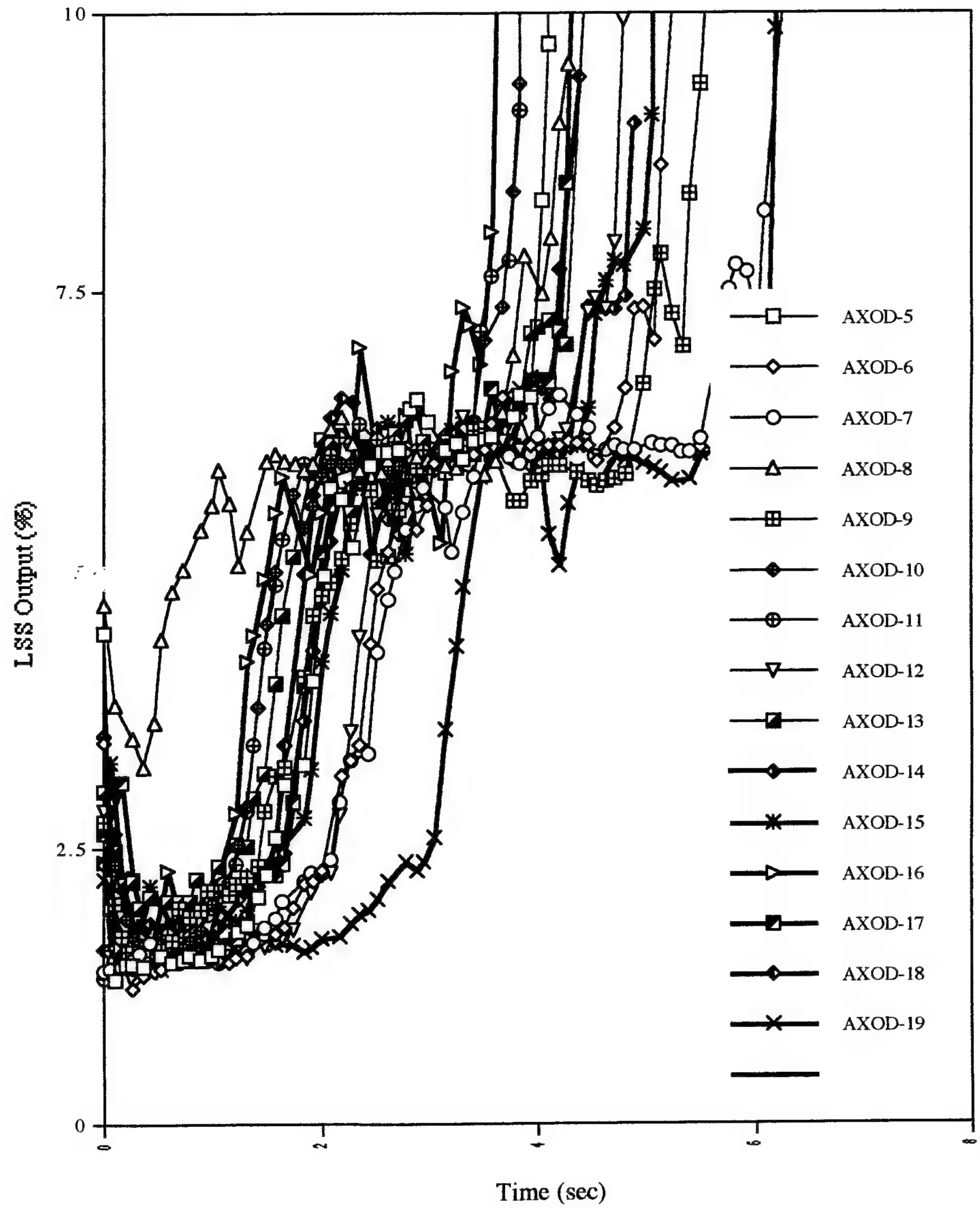
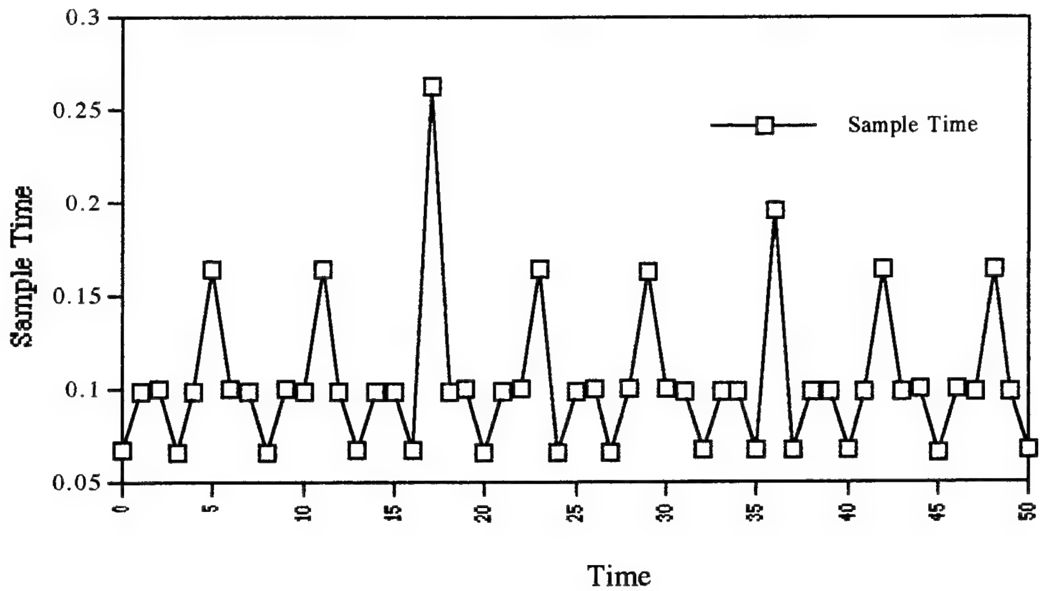


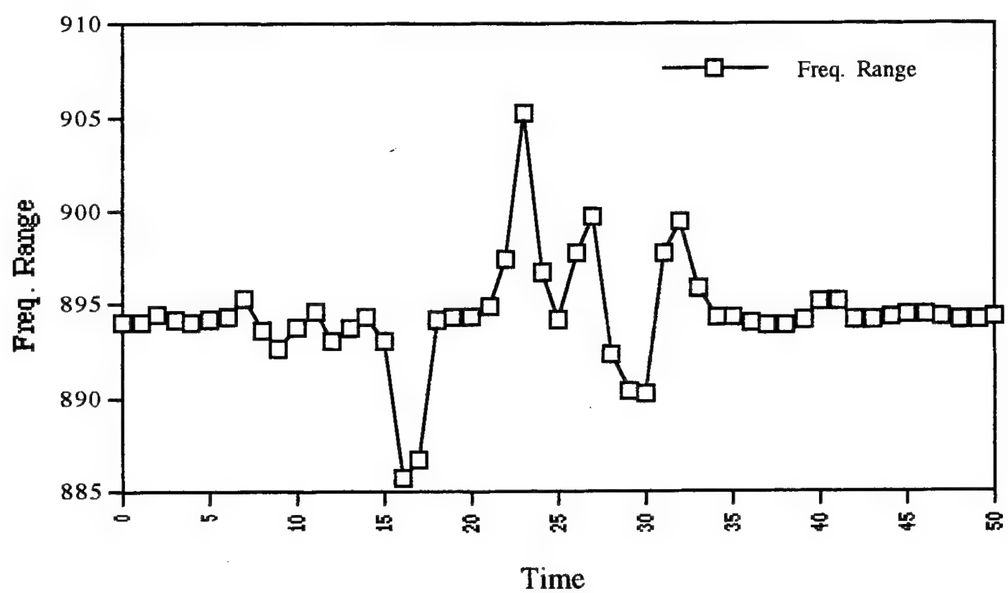
Figure 3 shows that sample time varies indicating that the Sparton computer interface software or hardware is not functioning properly. Correct sample time is 12 times a second or 0.083 seconds.

Figure 3 Sample Time



The stability of the voltage controlled oscillator in the expendable probe as measured by the Sparton interface card is shown in figure 4. This data shows very poor frequency stability when compared to similar data taken with the Sea Tech computer interface showing a fraction of a hertz variation. While it can be argued that the output data is radiometric so a change in frequency range is unimportant, still the performance shown is less than desirable. The data shows either a edge jitter or processor timing problem with the Sparton computer interface.

Figure 4 Frequency Range Stability, NXO48_16



Optical Data:

Figure 5 is a profile of the beam attenuation and beam absorption coefficient at 880 nm taken during cast 20. The pure water values were subtracted from the data giving the values due to the suspended particle absorption, ap and the attenuation, cp. It is clear from the data that very little energy is absorbed by the particulate matter in the water. Since a+b=c and a is small as the data shows then b is very nearly equal to c for the suspended material in Green Peter reservoir.

Figure 5 880 nm ap & cp

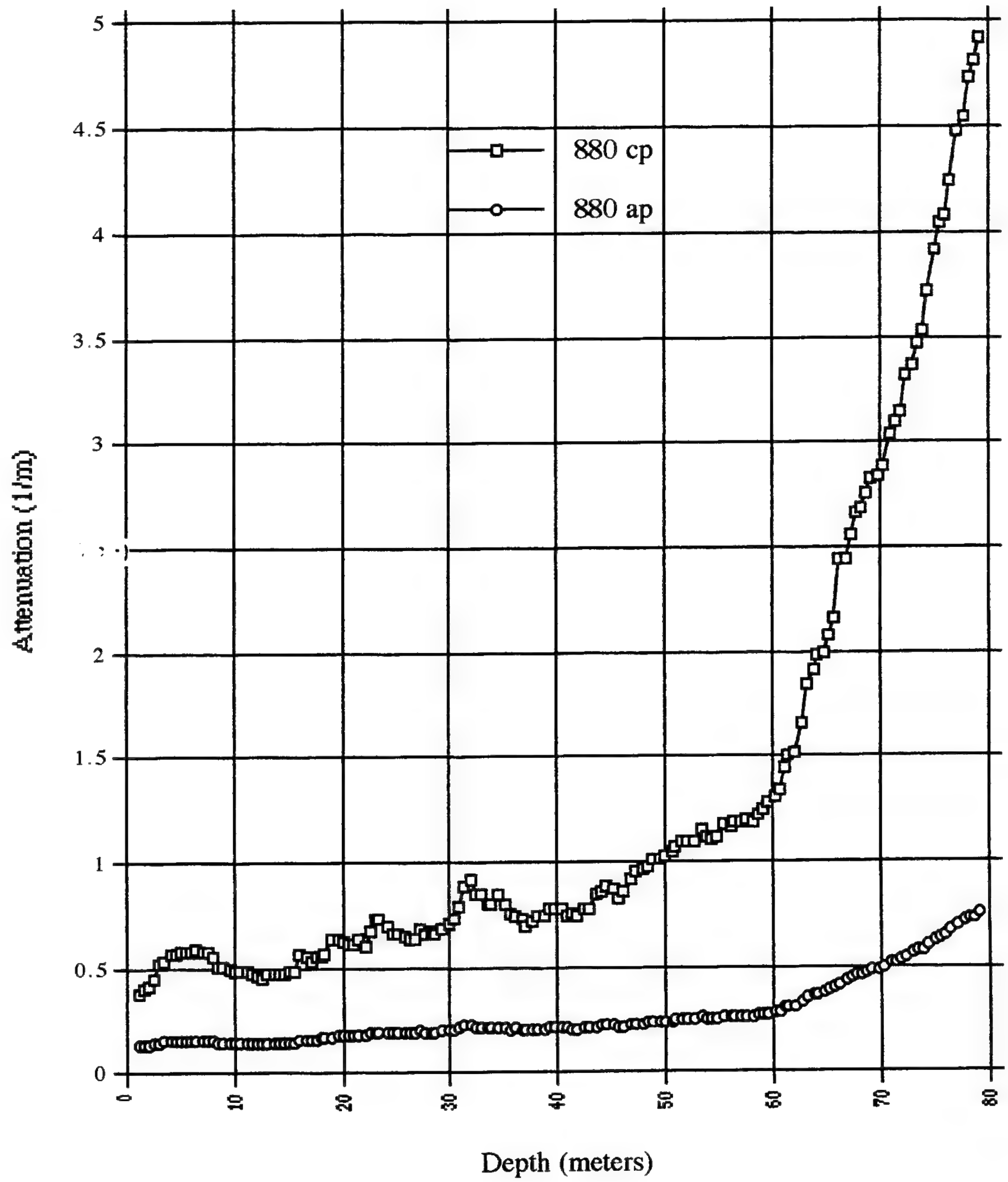


Figure 6 is the profile obtained during cast 20 and is shown to demonstrate the correlation between all the inherent optical properties. There is a good correlation between any of these optical properties and suspended particulate material in the water given that the nature of the particles do not change.

Figure 6 Green Peter Reservoir Profile, Cast 20

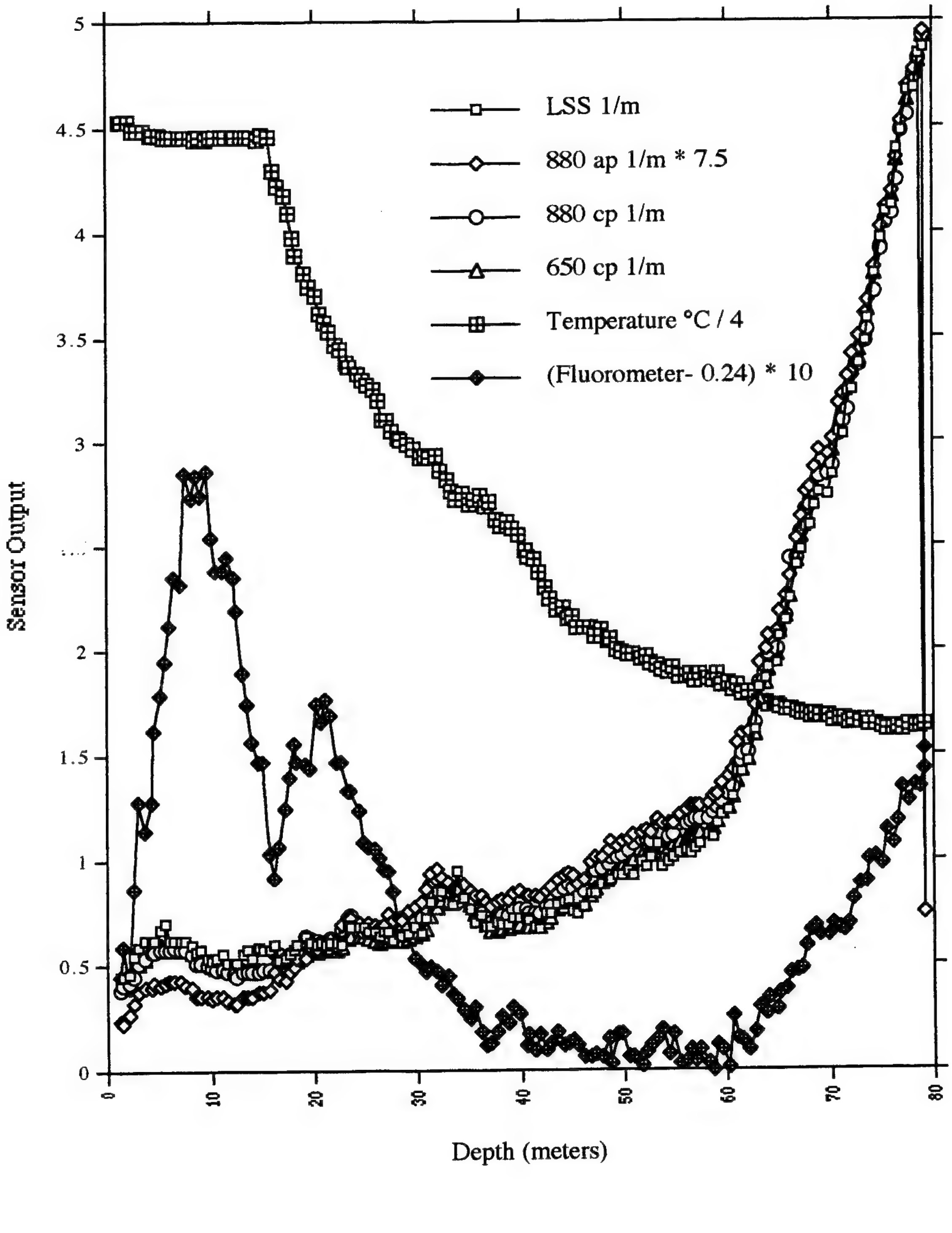


Figure 7 shows the unedited data from drop 17 where the probe was allowed to free fall through the water column. The data is overlaid with the data from cast 20. With the exception of the start up transient the data from the XOTD probe correlates very well with the cast data.

Figure 7 Fresh Water Profile, XOTD & LSS @ 880nm vs 880nm cp & 650nm cp

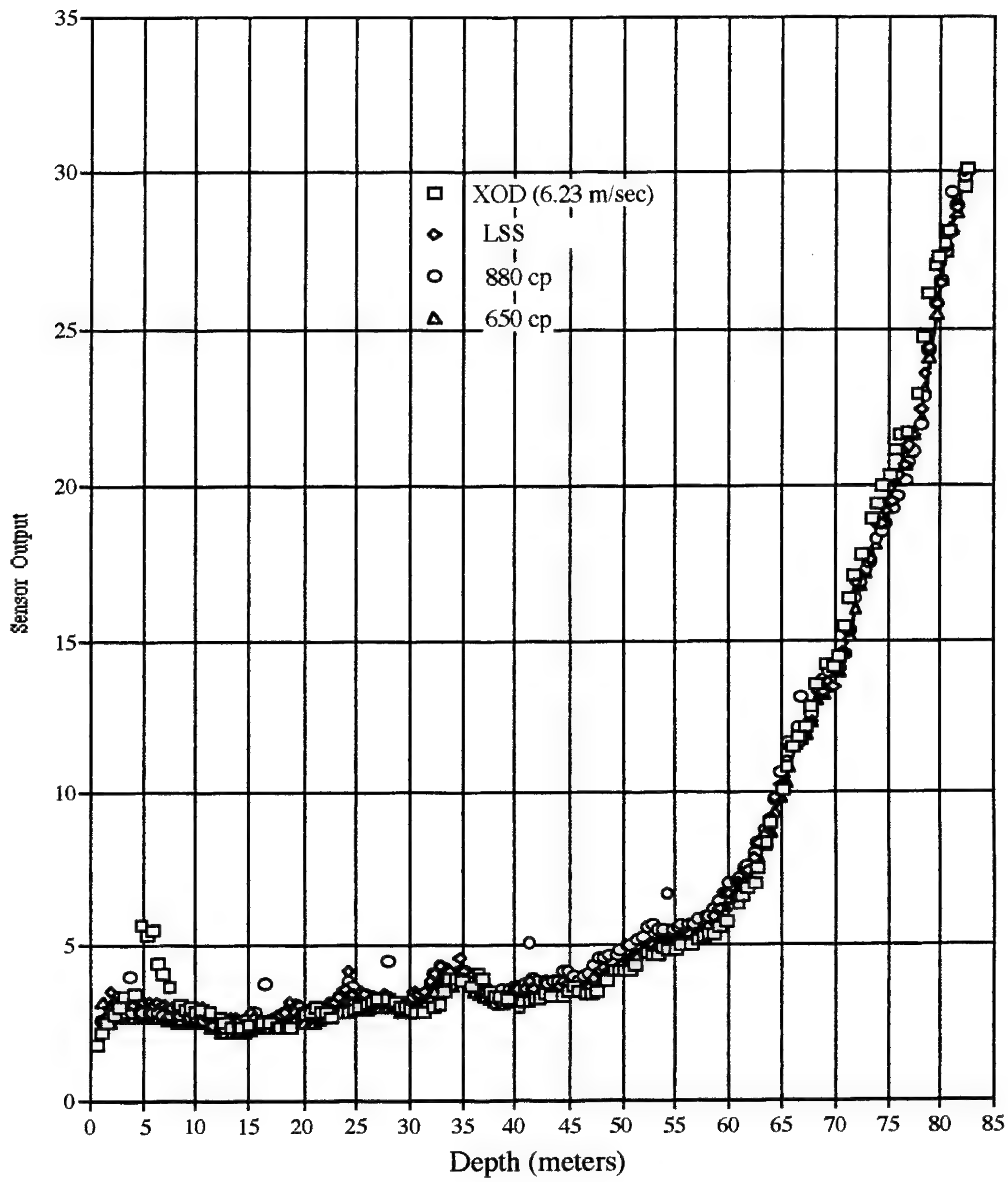


Figure 8 shows the beam attenuation at 660 nm for casts 1 through 9. The suspended material in the water column is very stable permitting stability of expendable probes as well as the non-expendable probes to evaluated with a high degree of accuracy.

Figure 8 Cast 1 to 9, 650 nm cp

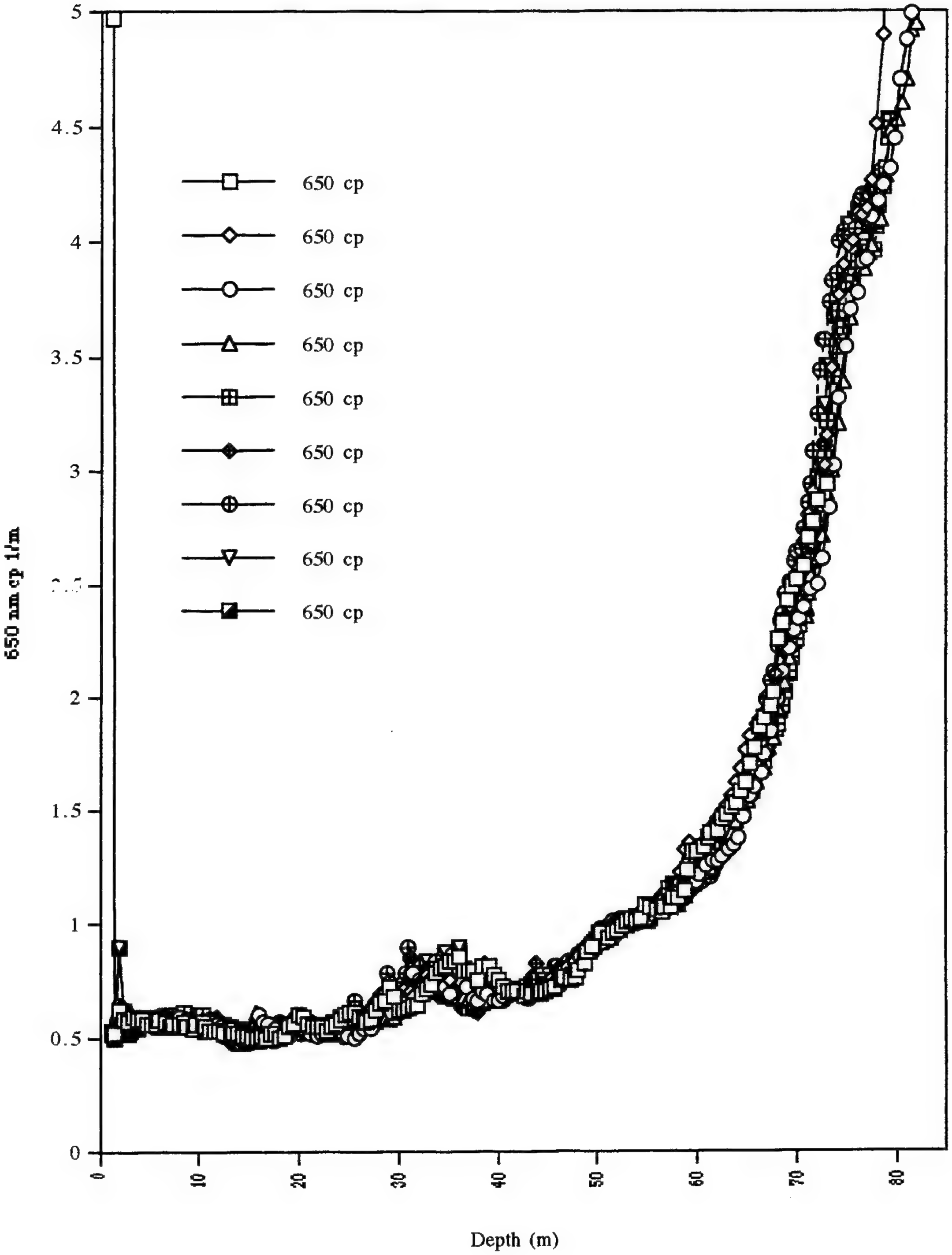
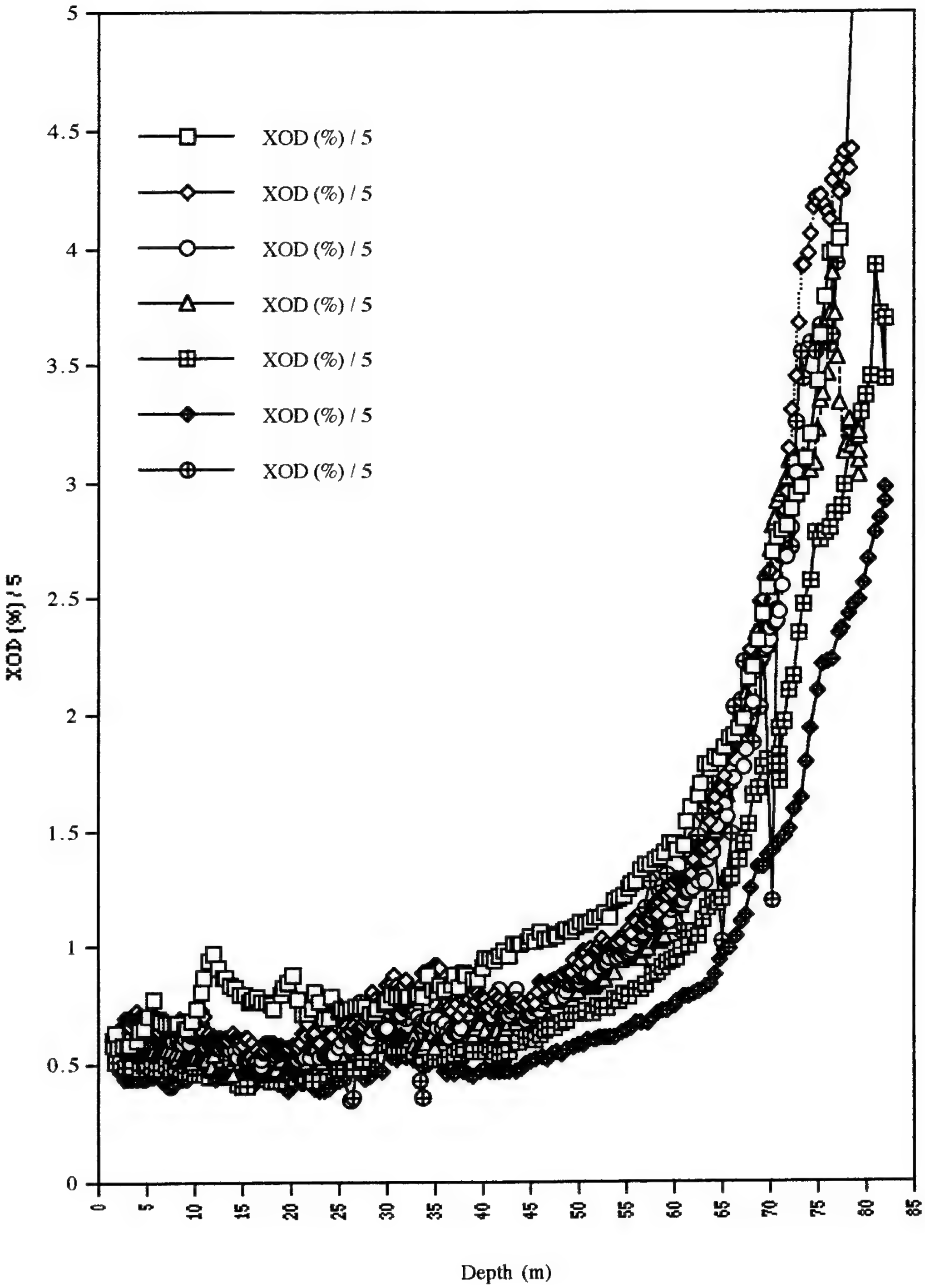


Figure 9 shows the XOTD optical sensor output for casts 1 through 9 and this data correlates well with the data in figure 8. No further data will be presented in this section of the progress report since it now should be obvious that their is a good correlation between the light scattering sensor output and the suspended particles in the water column.

Figure 9 Cast 1 to 9, XOTD Optical Sensor Output



Appendix C

Sample Volume in Water

The Sensitive Volume of the LSS for Low Particle Concentrations

The following simple but informative tests describe the sensitive volume for the light scattering sensor. The sensitive volume of the scattering meter for low concentrations was determined as follows: First, the sensor was tested in water with a low concentration of suspended clay particles giving a sensor output of 3.5 Volts. Then the scattering light in different areas of the sensitive volume was determined by taping over part of the emitter and detector windows with black electrical tape as explained below, refer to Figure 1.

1. The output due to back scattering in area I was measured by taping over the inside half of the emitter window. The sensor output was 0.5 Volts, or about 14% of the total.

2. The output due to back scattering in area VI was measured by taping over the inside half of the detector window. The sensor output was 0.3 Volts, or about 9% of the total.

3. The output due to forward scattering in area V was measured by taping over the outside 3/4 of the emitter window and the outside 3/4 of the detector window. The sensor output was 0.1 Volt, or about 3% of the total.

4. The output due to back scattering in area II was measured by taping over the outside half and inside 1/4 of the emitter window, and the outside half and inside 1/4 of the detector window. The sensor output was 1.1 Volts, or about 31% of the total.

5. The output due to back scattering in areas II and III combined was measured by taping over the outside half and the inside 1/4 of the emitter window. The output was 2.2 Volts, or about 63% of the total, so the output due to scattering in area III was 63%-31%, or 32% of the total.

6. The output due to back scattering from areas II and IV combined was measured by taping over the outside half and inside 1/4 of the detector window. The output was 2.0 Volts, or about 57% of the total, so the output due to scattering in area IV is 57%-31%, or 26% of the total.

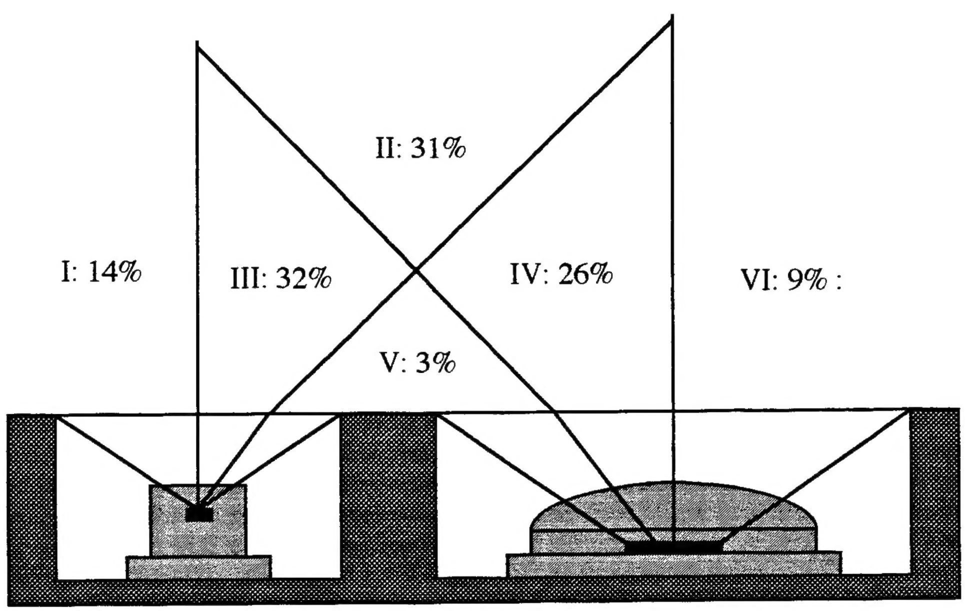


Figure 1 XOTD Light Sorce & Detector

The sum of the contributions of each of the areas is 115% of the total output of the sensor. One explanation for this is that the emitter and detector both have finite areas, and thus the areas I-VI are not really as simply defined as shown in Figure 1. In reality, these areas overlap one another, and so the measurements of the contributions from these areas included some scattered energy that was counted twice. Also, these measurements were relatively crude, and therefore we expected some error in the measurements.

This test demonstrates that the sensor configured as shown in Figure 1 measures predominantly back scattered light at low particle concentrations. Very little forward scattered light is measured.

The Sensitive Volume of the LSS for High Particle Concentrations

Tests were also performed at high particle concentrations, (on the order of 1 g/l). to approximately determine the sensitive volume of the LSS. Again with a very simple but informative test, we taped over the inside half of the emitter window and the inside half of the detector window and immersed the sensor in the high concentration solution. When we did this in low concentrations, we received no scattered light since single scattered light was prevented from reaching the detector. In the high concentration solution, however, the output of the taped sensor was almost 50% of its output without the tape. Thus, it was clear that multiple scattering is the dominant mechanism for light scattering at high concentrations.

To determine the size of the sensitive volume at high particle concentrations, approximately 1 g/l we taped the wall of a 100 ml beaker with black electrical tape to reduce reflections and then placed the sensor near the wall to determine when the output changed. We found that when the sensor was as close as 5 mm from the beaker wall, its output changed less than 20% from its output in the center of the beaker . Thus, at high concentrations the sensitive volume is very close to the sensor surface and it measures predominantly multiple scattered light.

LSS light beam in Water:

Figure 1 and figure 2 show the LSS radiance and irradiance distribution in water. Sensor orientation is shown since the beam in not symmetrical. The double peak in the light beam results from two LED's spaced some distance apart and as expected the light detector has nearly a cosine response.

Figure 2 Expendable Scattering Sensor Light Source Radiation Pattern in Water

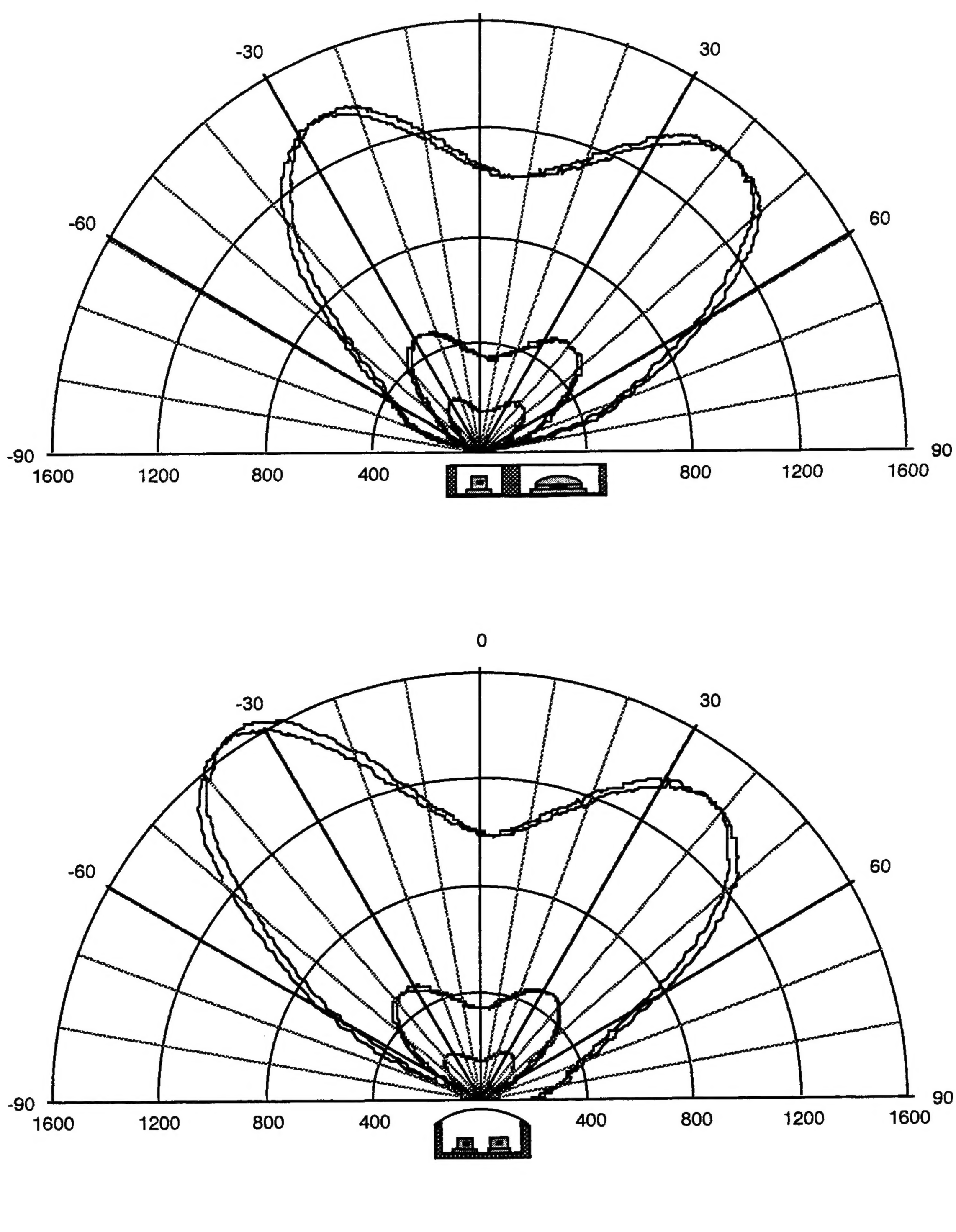


Figure 3 Expendable Scattering Sensor Detector Irradiation Pattern in Water